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(54) **DISCOVERY SIGNAL MEASUREMENT
TIMING CONFIGURATION FOR SCELLS IN
ASYNCHRONOUS NETWORKS**

(71) Applicant: **TELEFONAKTIEBOLAGET LM
ERICSSON (PUBL)**, Stockholm (SE)

(72) Inventors: **Emma Wittenmark**, Lund (SE); **Peter
Alriksson**, Hörby (SE); **David
Sugirtharaj**, Lund (SE); **Mai-Anh
Phan**, Herzogenrath (DE)

(73) Assignee: **Telefonaktiebolaget LM Ericsson
(publ)**, Stockholm (SE)

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CPC ... **H04W 72/0426** (2013.01); **H04W 72/0453**
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76/27 (2018.02)

(58) **Field of Classification Search**
None
See application file for complete search history.

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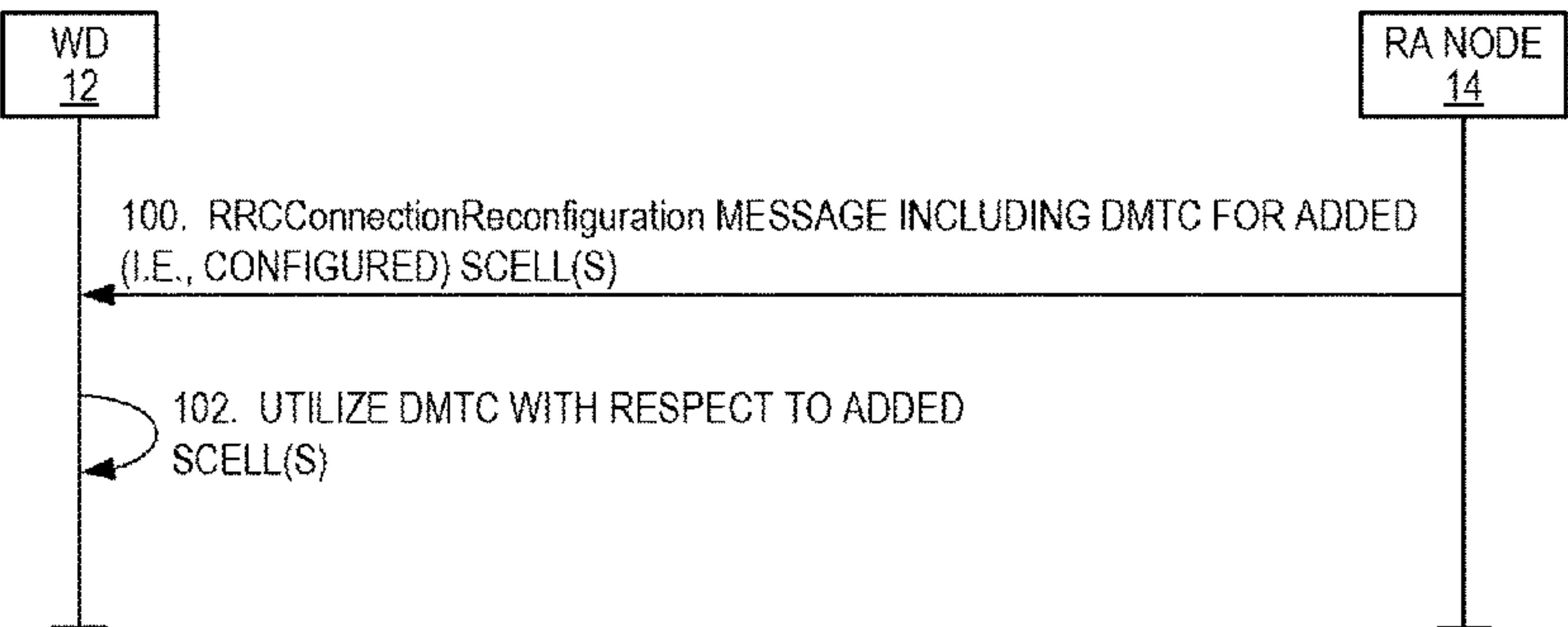
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Primary Examiner — Steve R Young
(74) *Attorney, Agent, or Firm* — Withrow & Terranova,
PLLC

(57) **ABSTRACT**

Systems and methods relating to Discovery Signal Measure-
ment Timing Configuration (DMTC) are disclosed. In some
embodiments, a method of operation of a radio access node
in a cellular communications network comprises sending, to
a wireless device, a DMTC for one of a group consisting of:
(a) a Secondary Cell (SCell) configured for the wireless
device such that the DMTC is a specific DMTC for the SCell
and (b) a frequency on which one or more asynchronous
cells are operating, an asynchronous cell being a cell that is
unsynchronized with a Primary Cell (PCell) of the wireless
device. A DMTC configuration that is specific to a SCell
provides improved measurement performance on the SCell
because, e.g., the DMTC configuration can be specifically
tailored to that SCell. A DMTC configuration for a fre-
quency on which one or more asynchronous cells are
operating provides improved measurement performance on
that carrier.

18 Claims, 13 Drawing Sheets



Related U.S. Application Data

(60) Provisional application No. 62/347,543, filed on Jun. 8, 2016.

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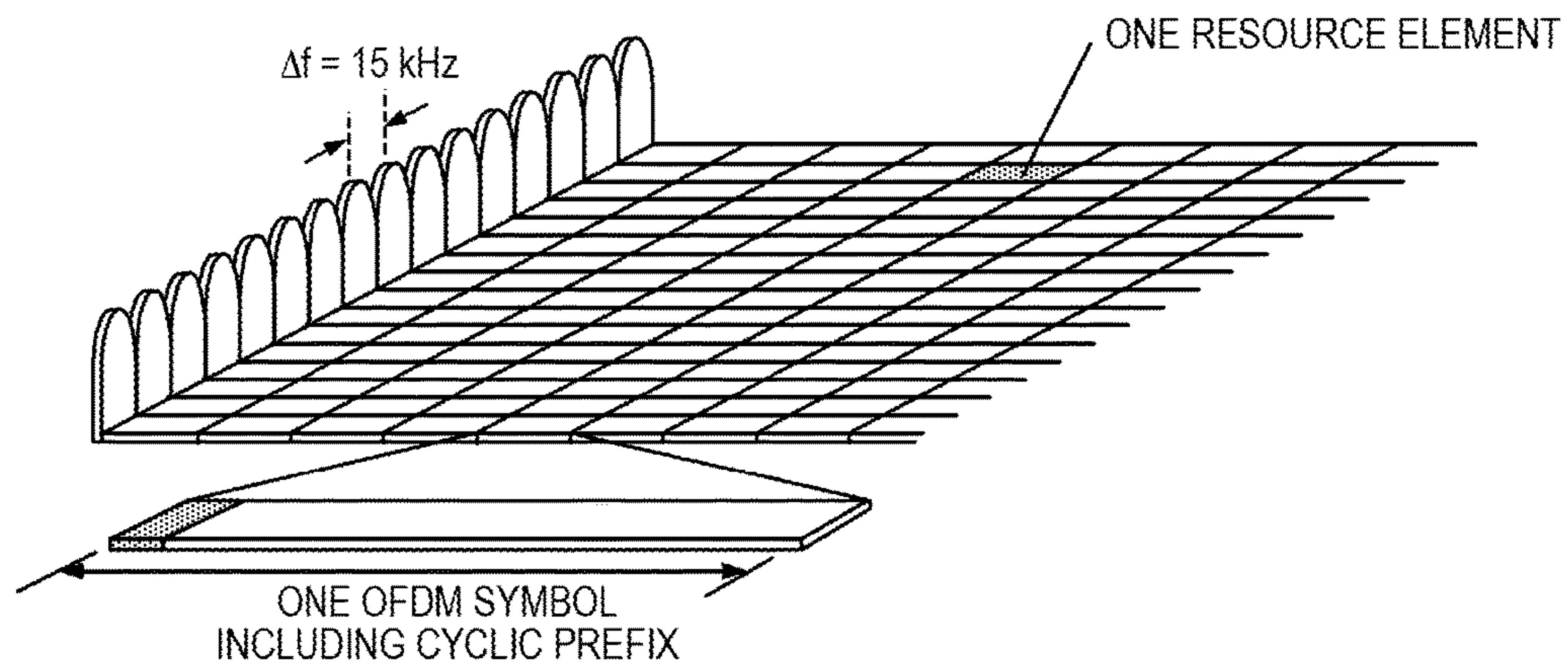


FIG. 1

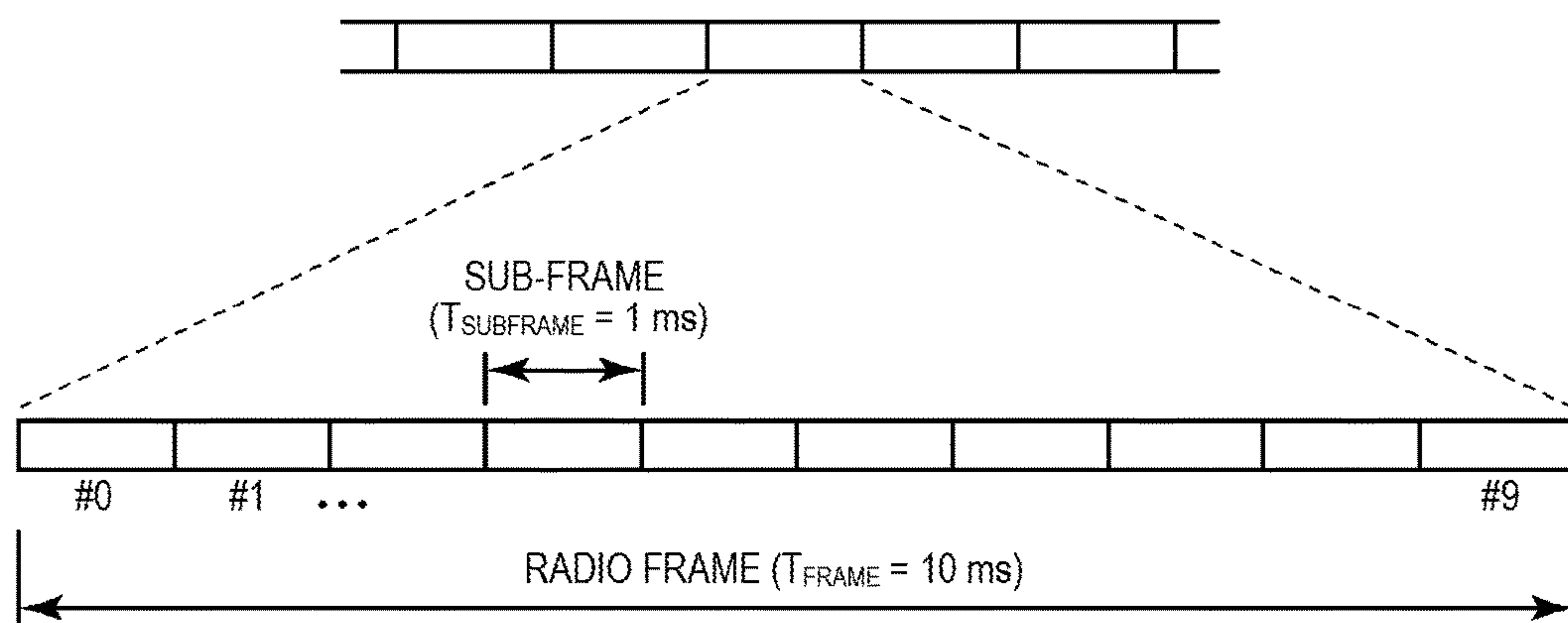


FIG. 2

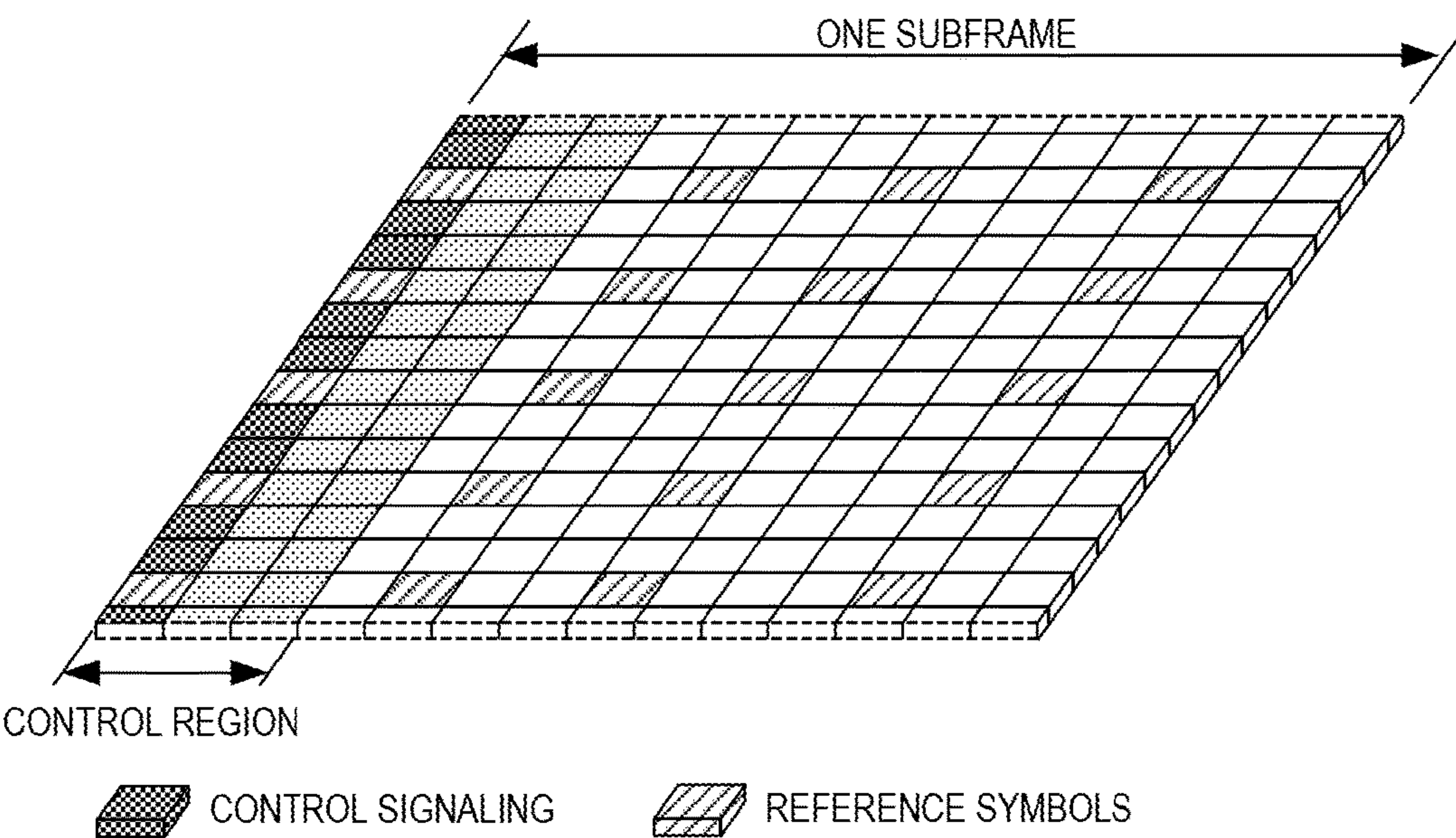


FIG. 3

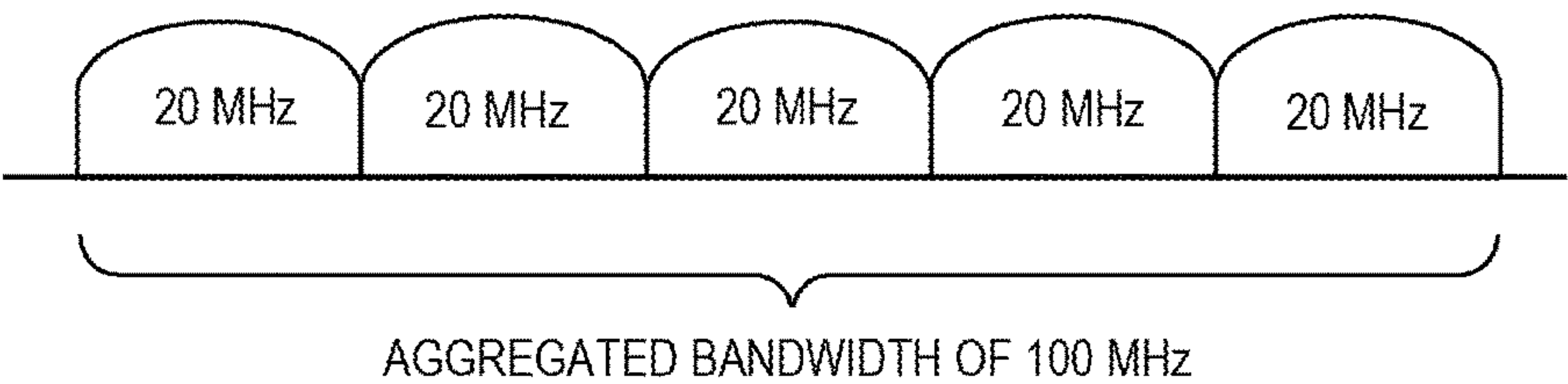


FIG. 4

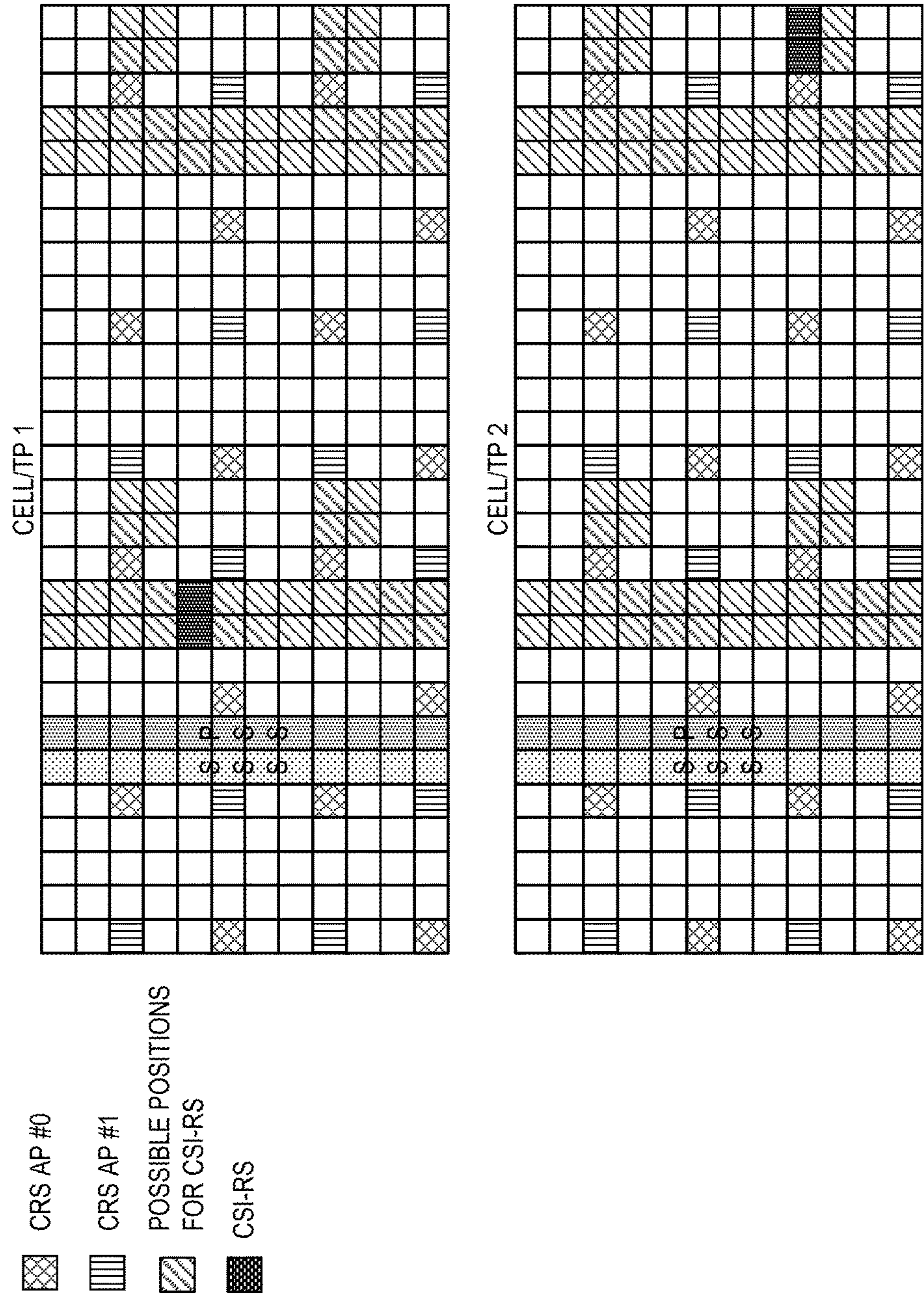


FIG. 5

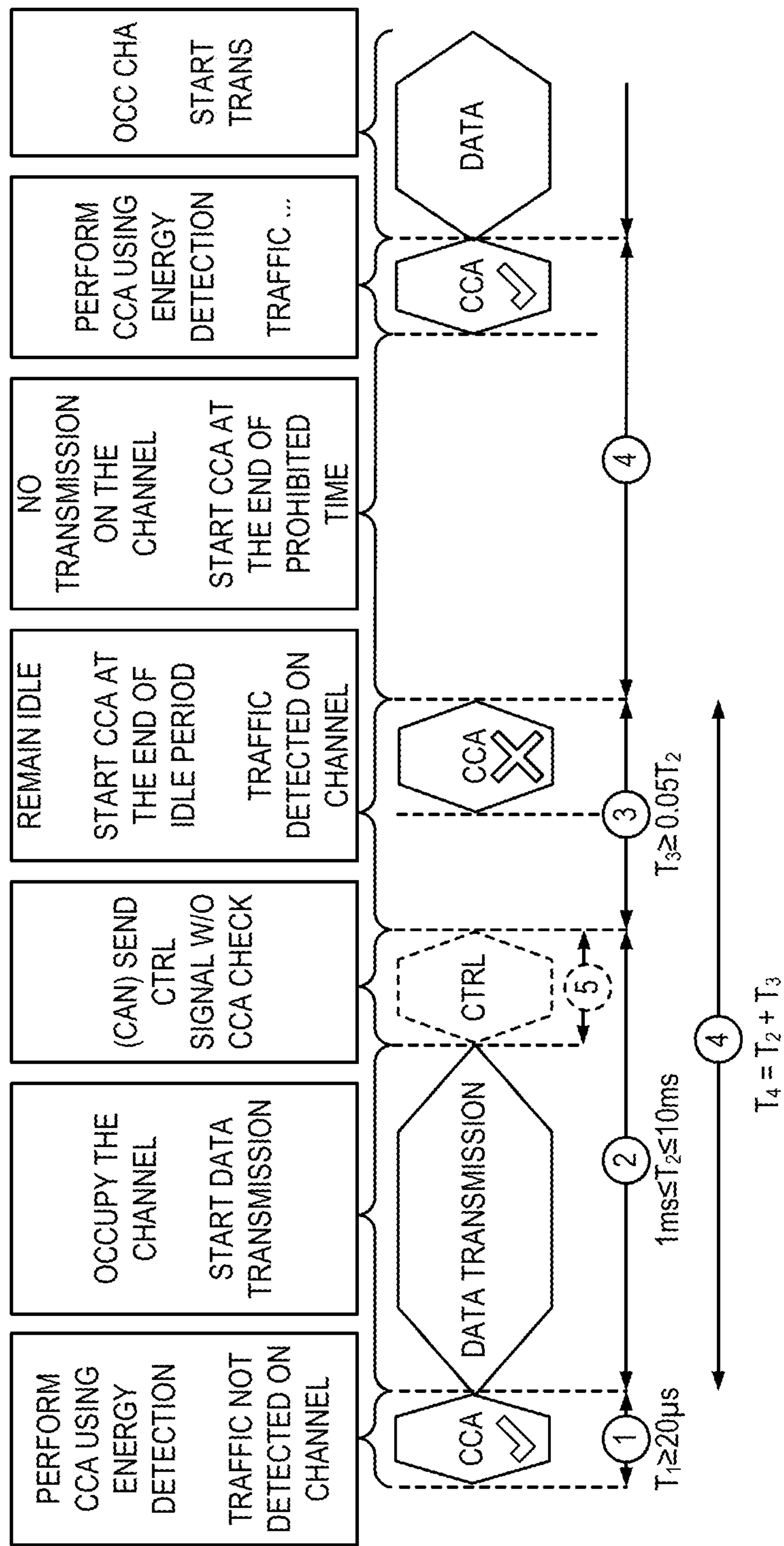


FIG. 6

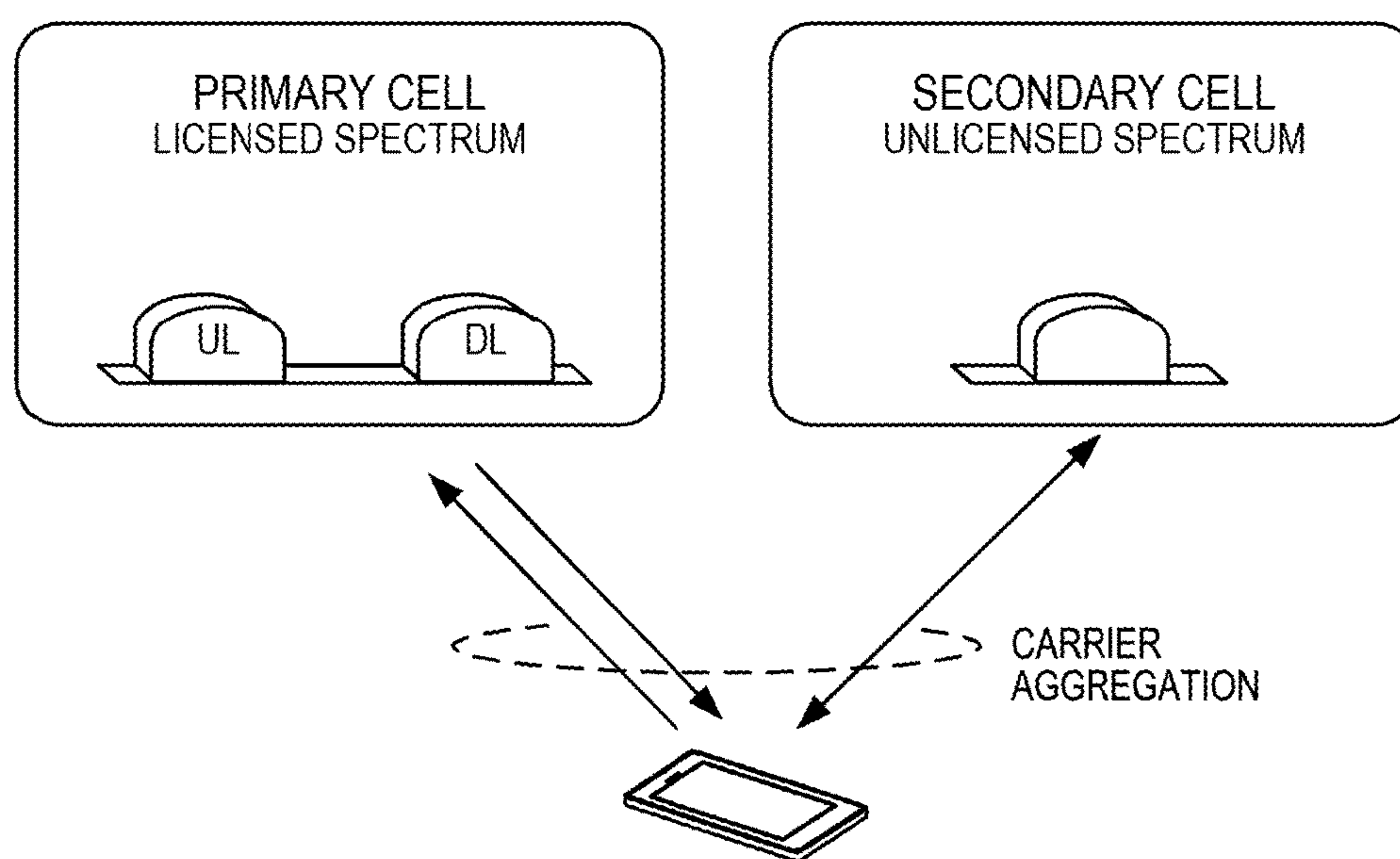


FIG. 7

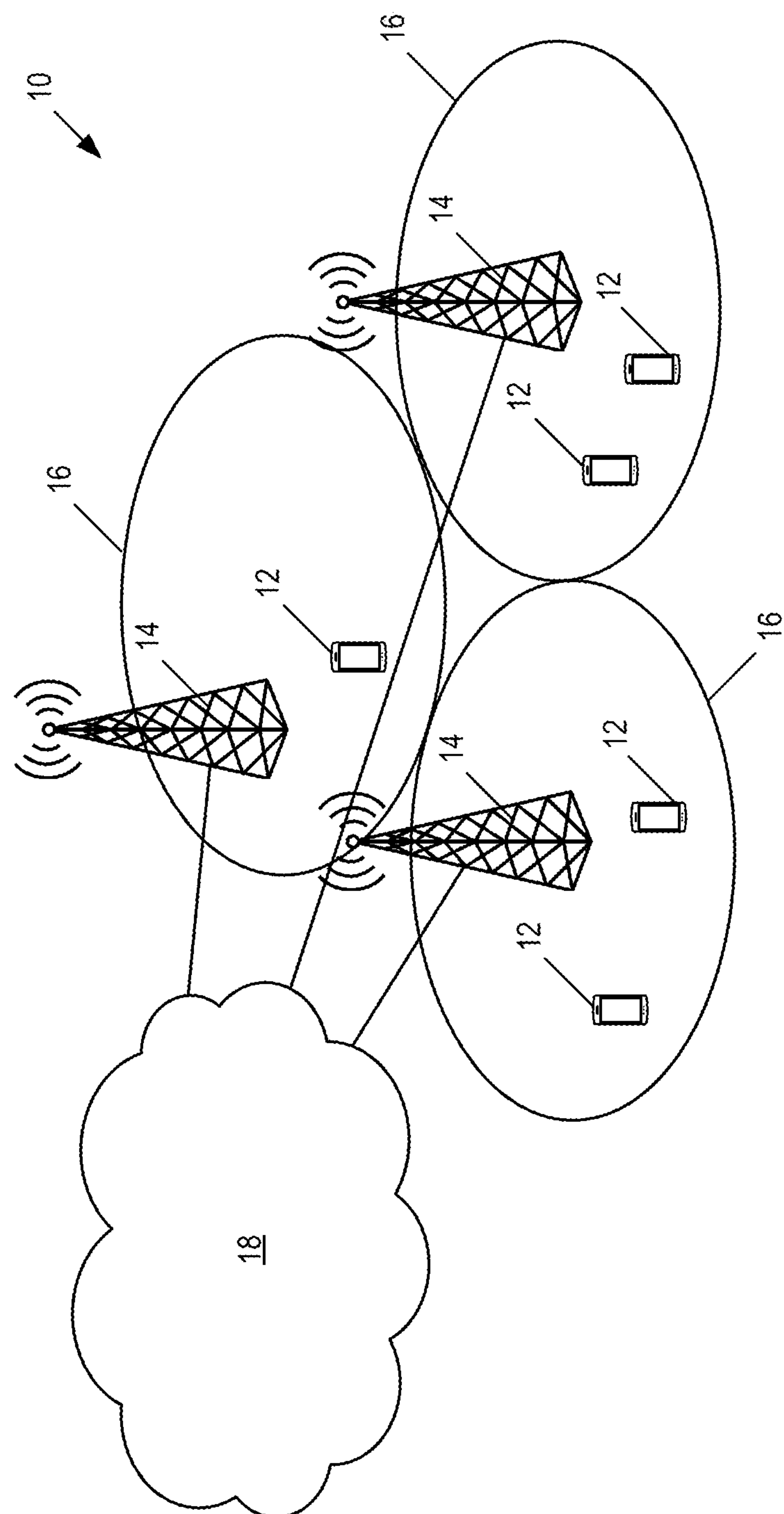


FIG. 8



FIG. 9

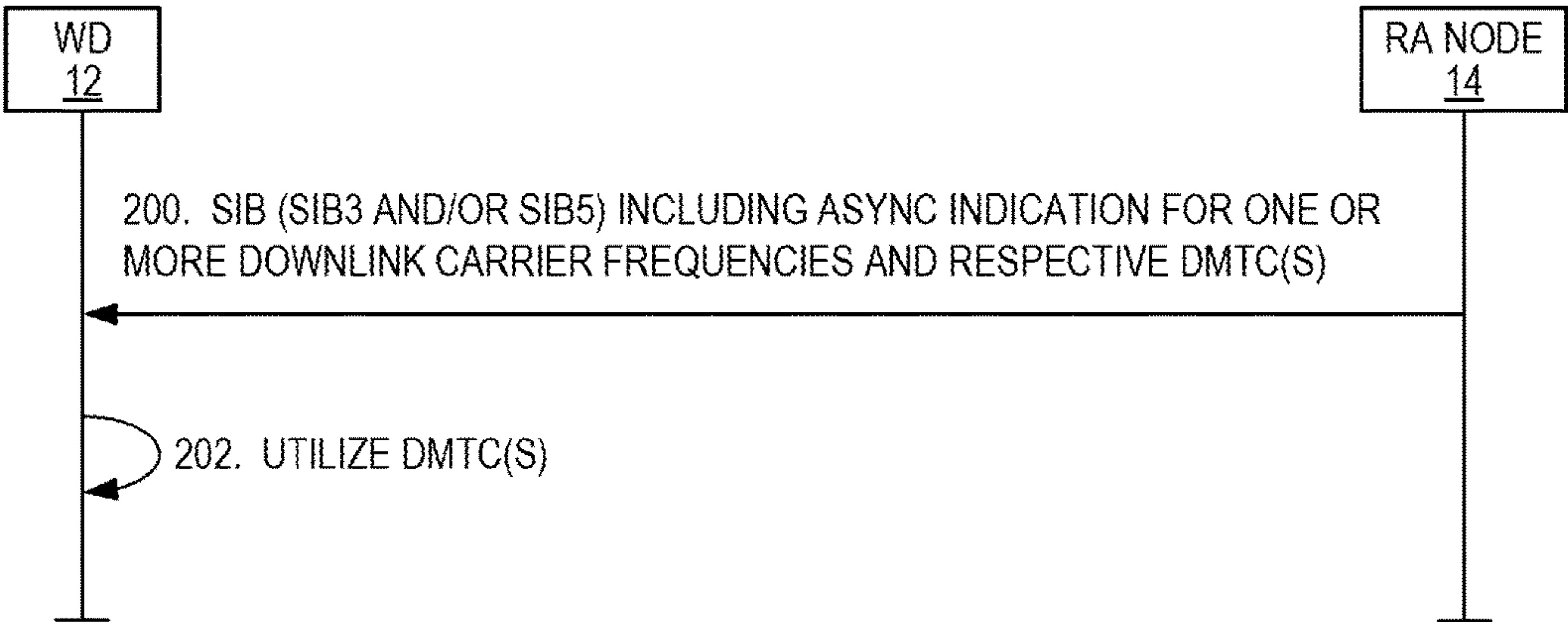
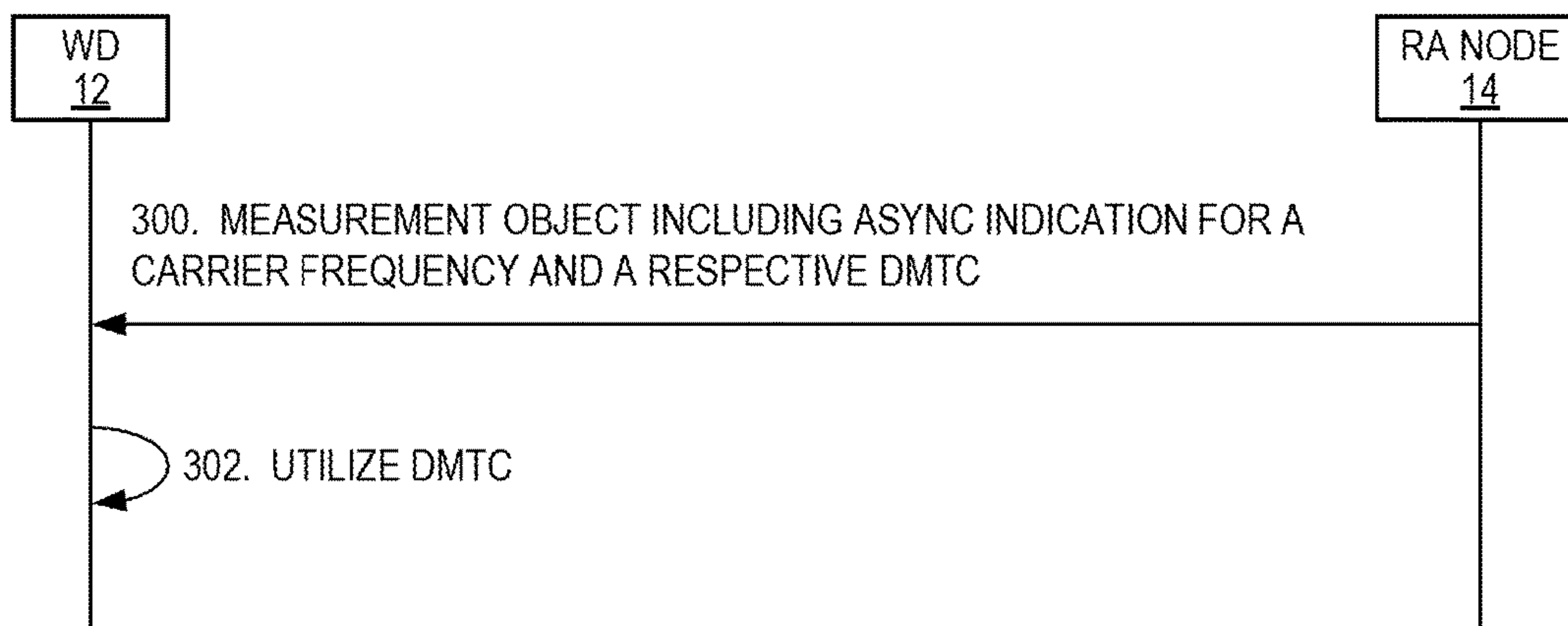
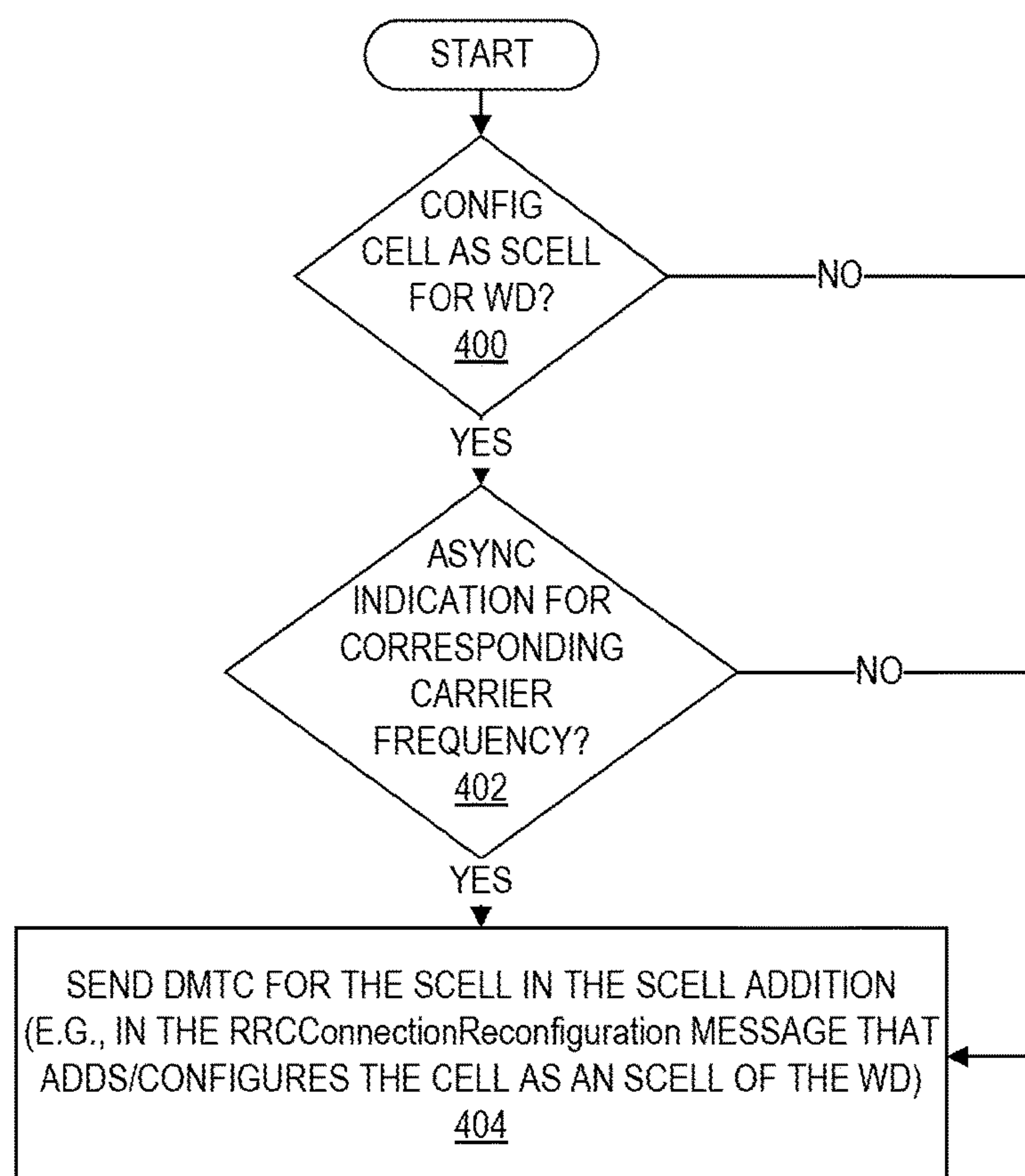
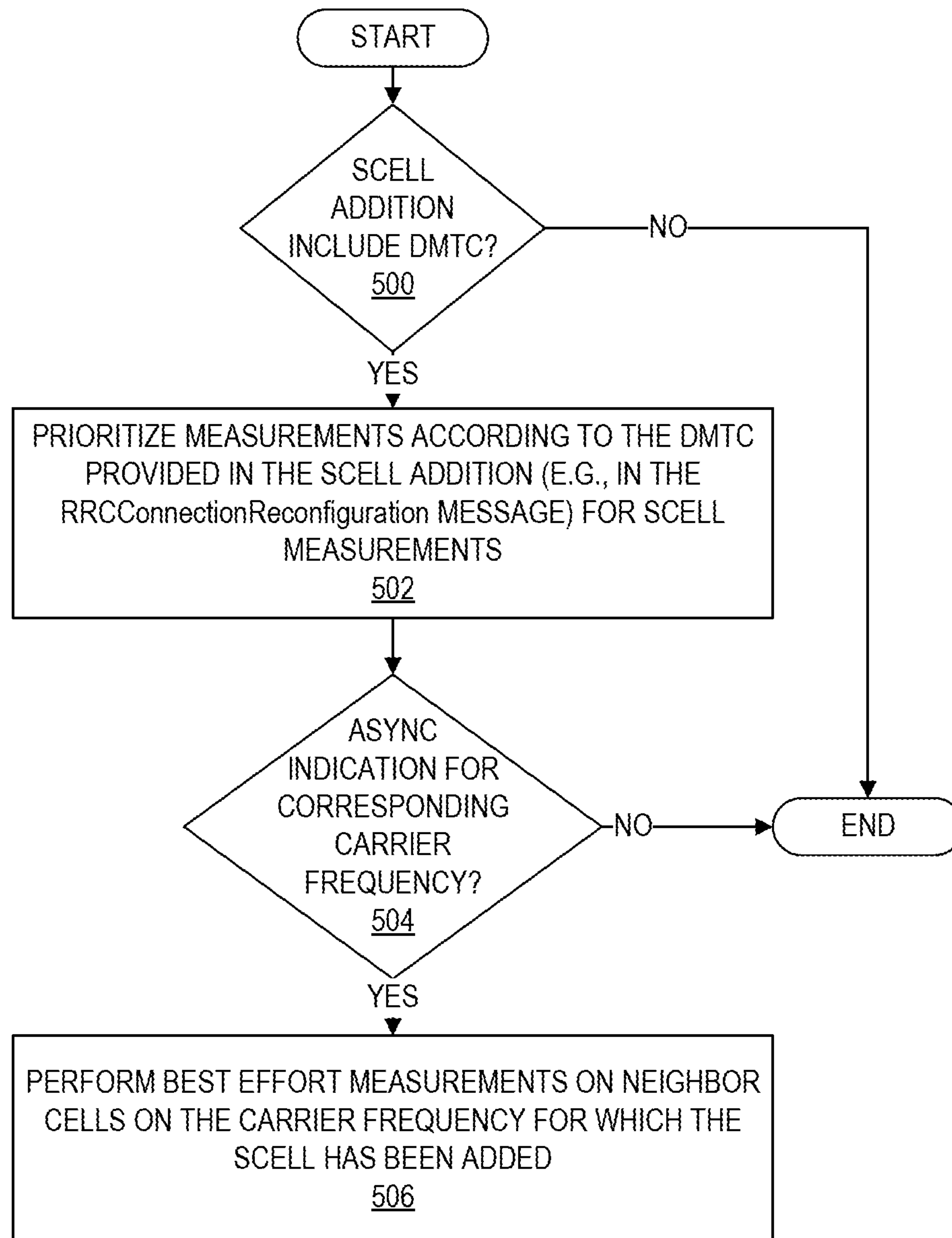
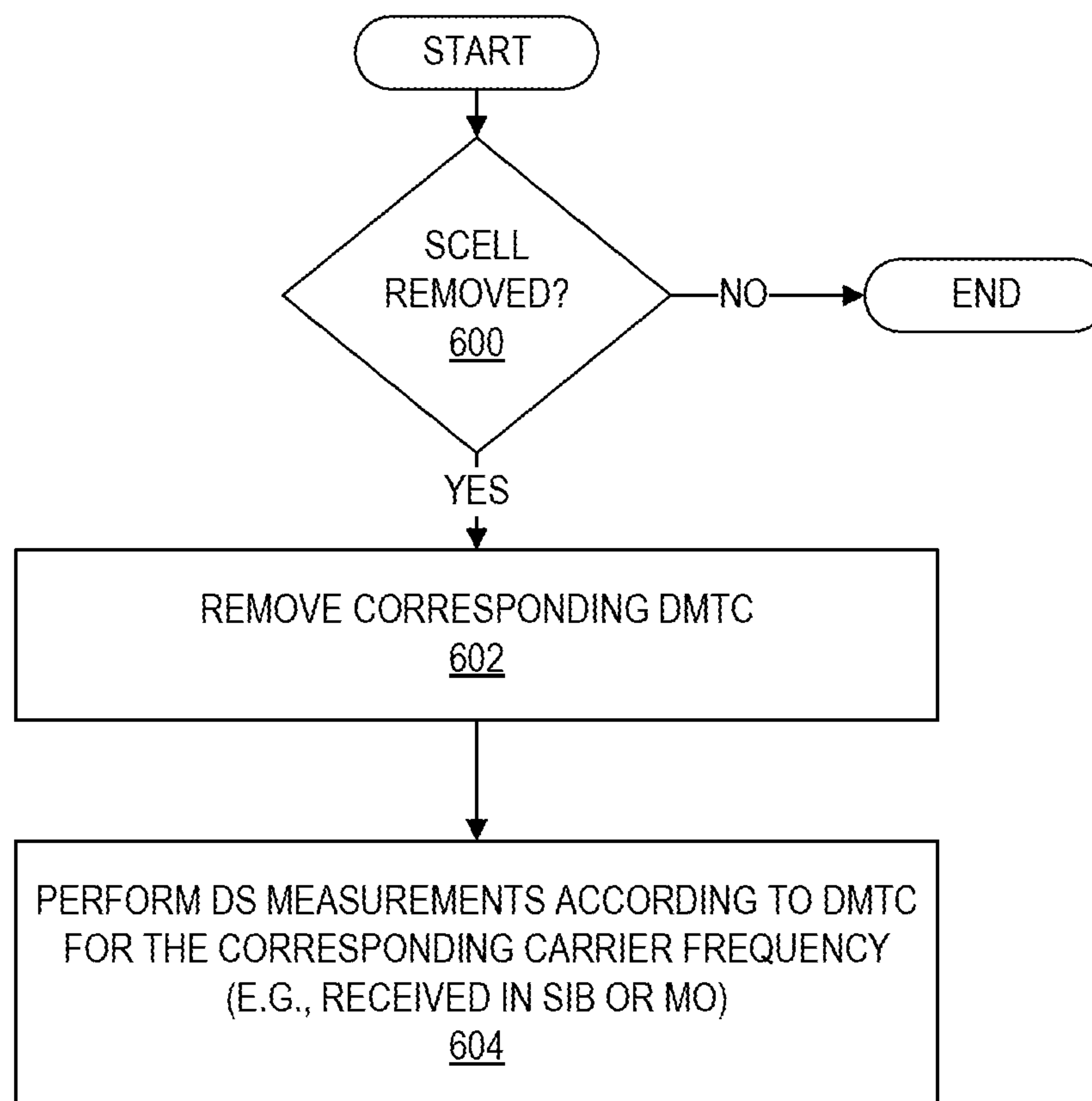


FIG. 10

**FIG. 11****FIG. 12**

**FIG. 13**

**FIG. 14**

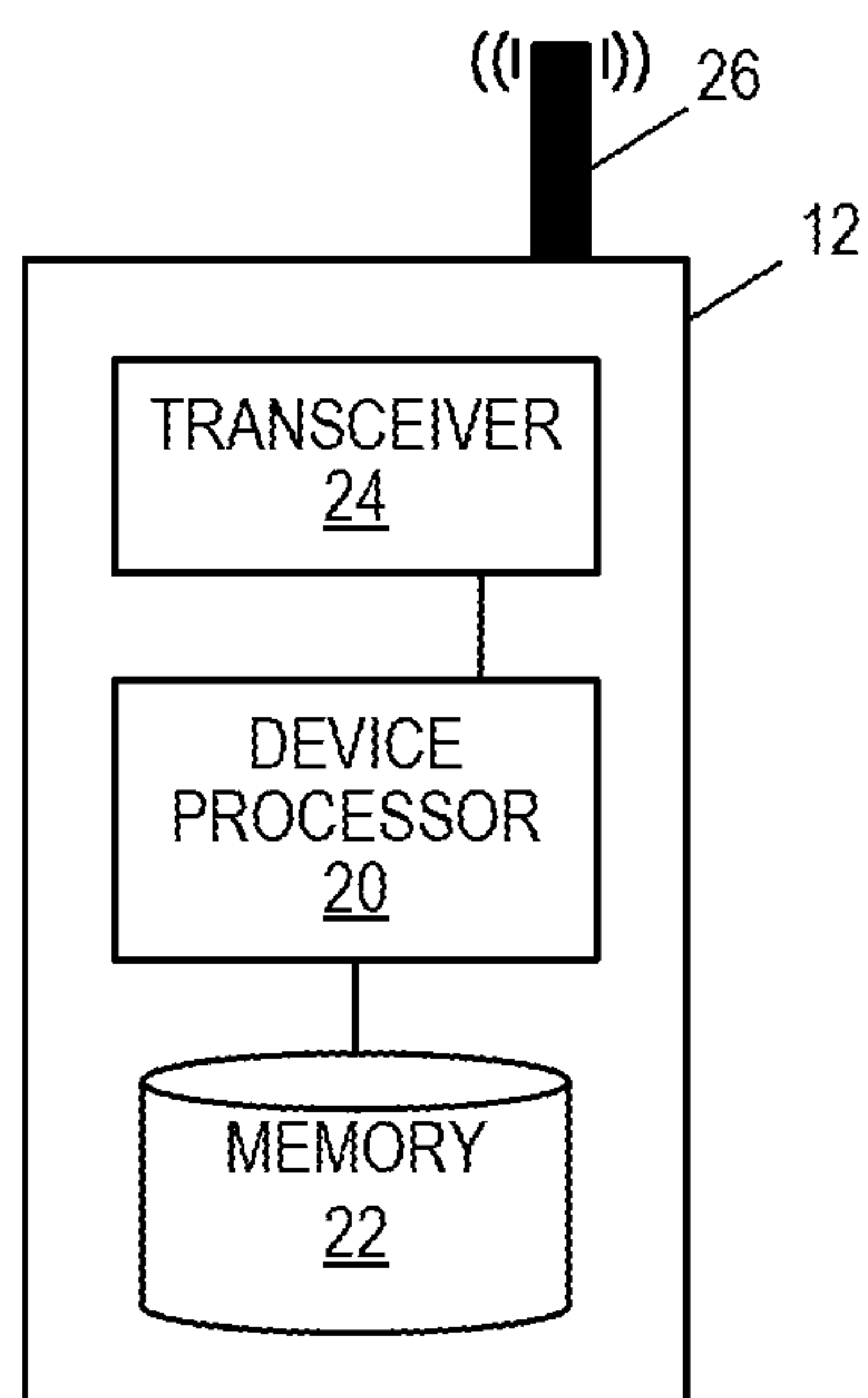


FIG. 15

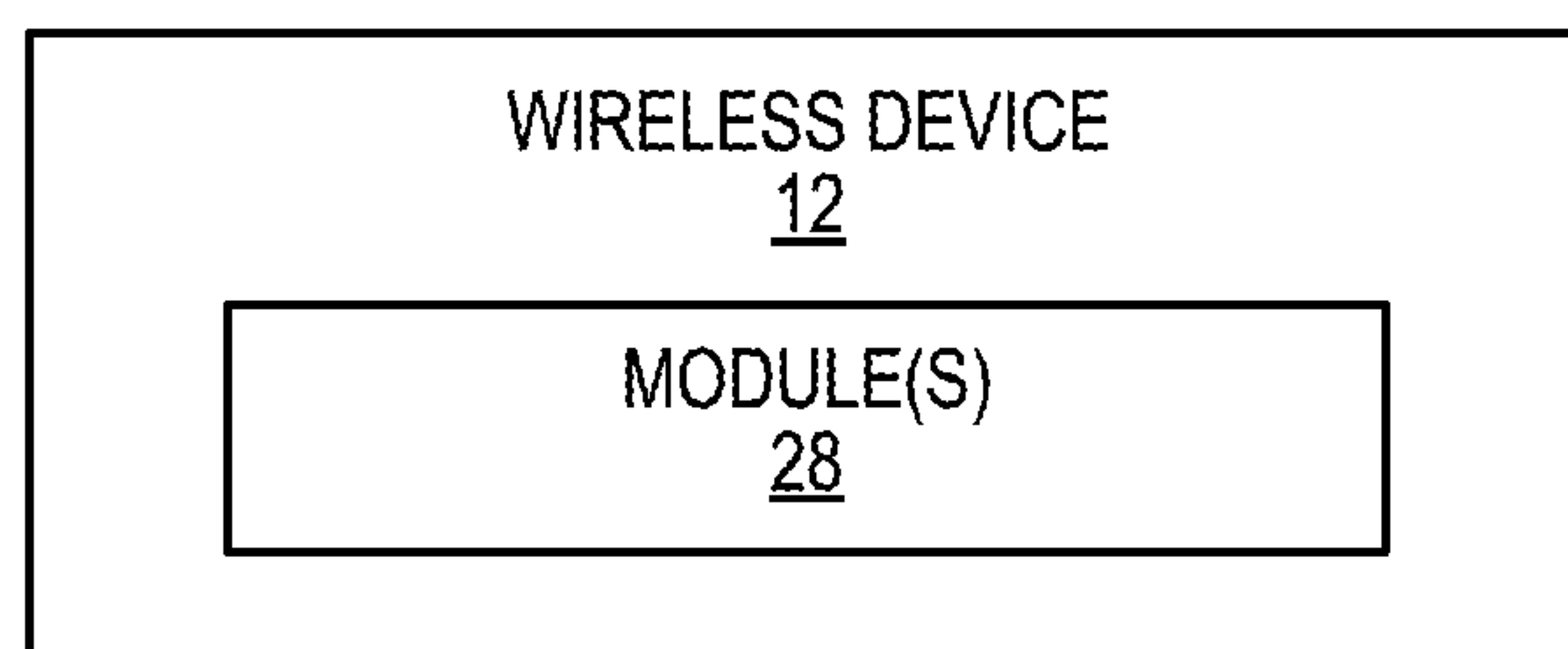


FIG. 16

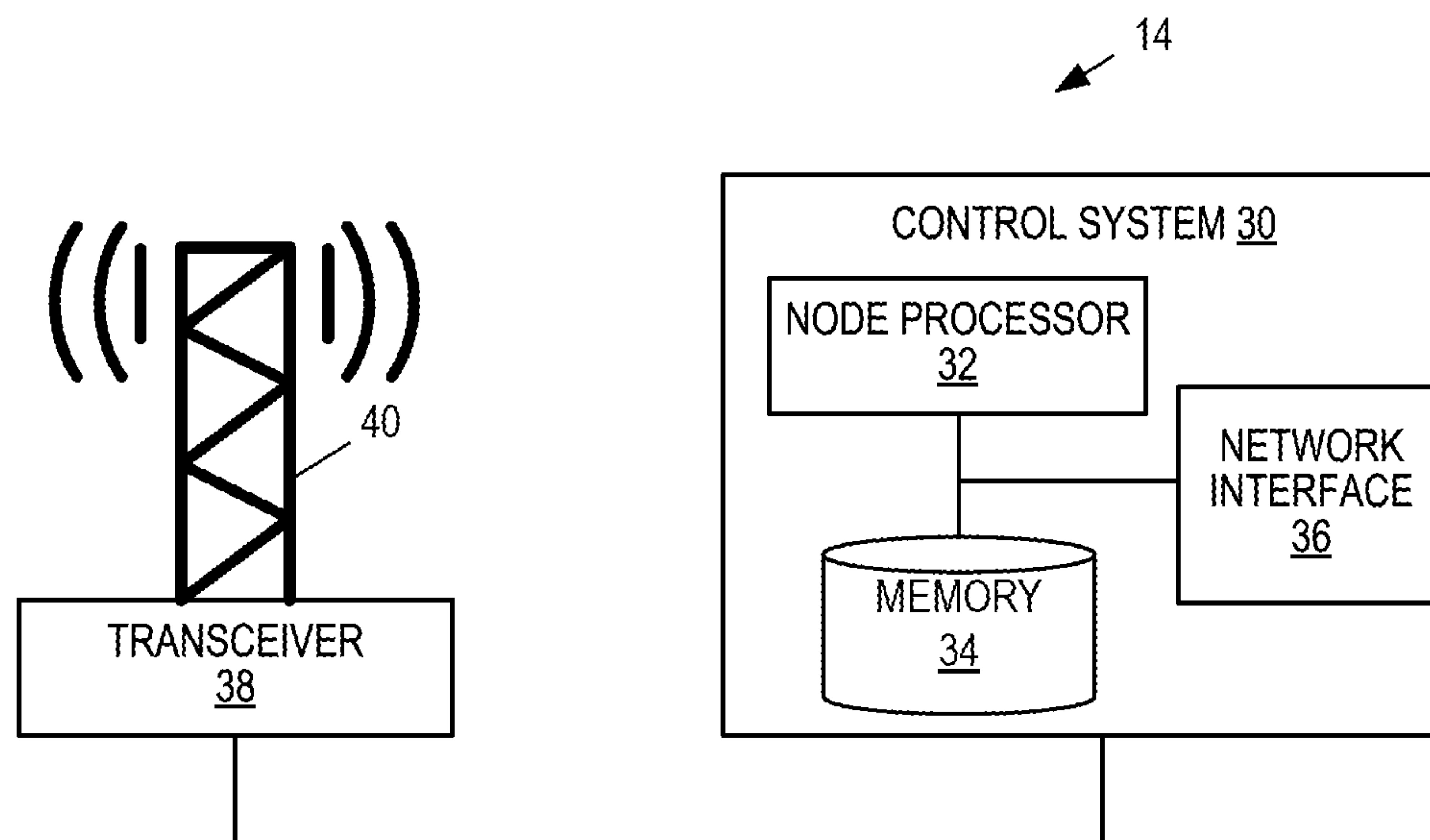


FIG. 17

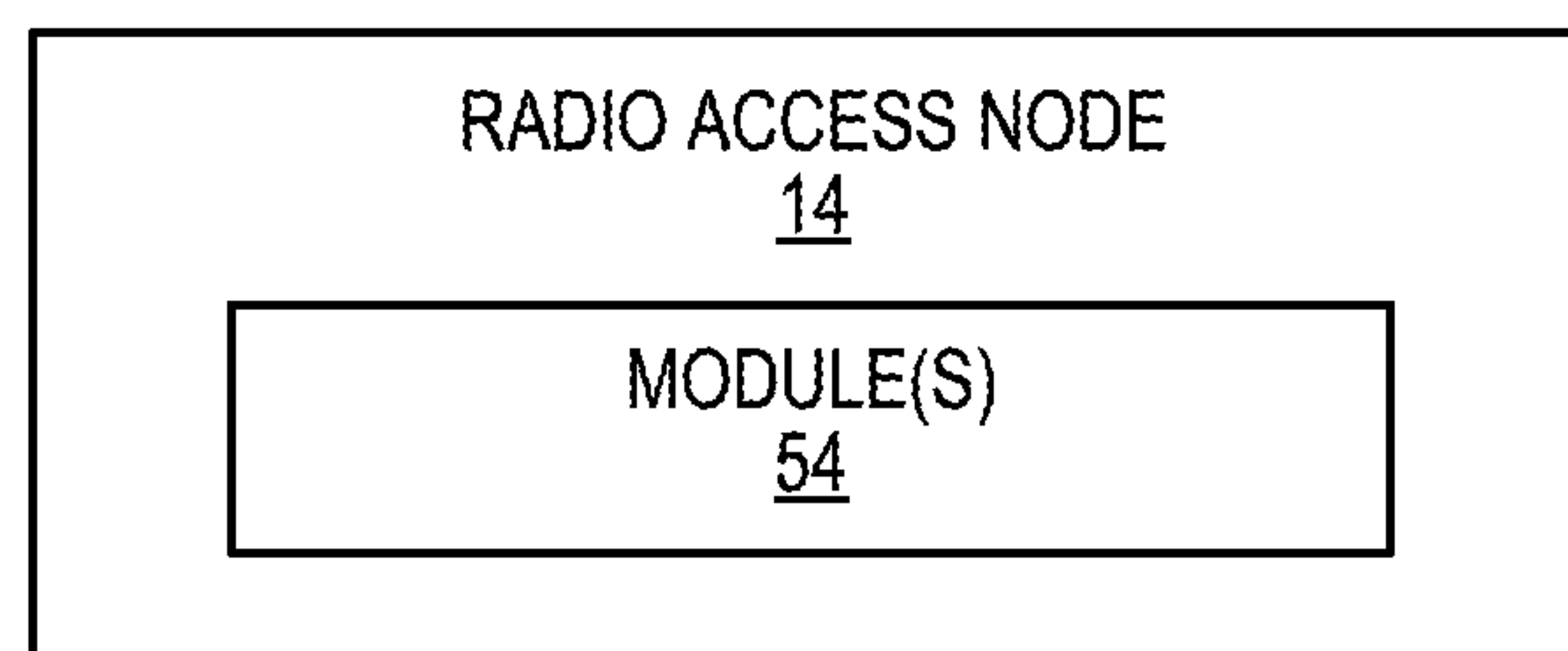


FIG. 19

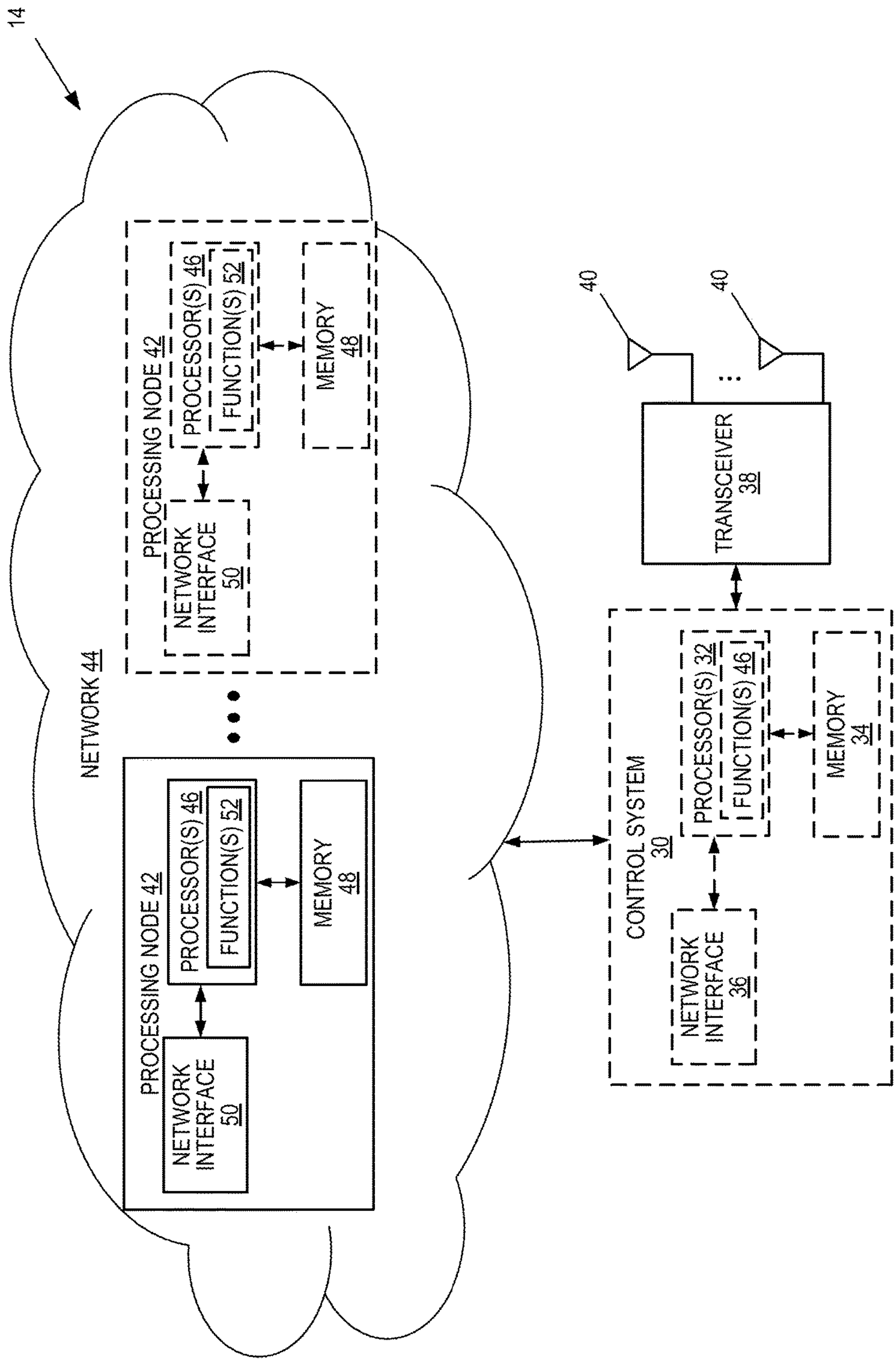


FIG. 18

DISCOVERY SIGNAL MEASUREMENT TIMING CONFIGURATION FOR SCELLS IN ASYNCHRONOUS NETWORKS

RELATED APPLICATIONS

This application is a continuation of International Application No. PCT/IB2016/057062, filed Nov. 23, 2016, which designated the United States, and which claims the benefit of provisional patent application Ser. No. 62/347,543, filed Jun. 8, 2016, the disclosures of which are incorporated herein by reference in their entirety.

TECHNICAL FIELD

The disclosed subject matter relates generally to telecommunications and more particularly to Discovery Signal Measurement Timing Configuration (DMTC) for Secondary Cells (SCells) in asynchronous networks.

BACKGROUND

The Third Generation Partnership Project (3GPP) initiative "License Assisted Access" (LAA) intends to allow Long Term Evolution (LTE) equipment to also operate in the unlicensed radio spectrum such as the 5 Gigahertz (GHz) band. The unlicensed spectrum is used as a complement to the licensed spectrum. Accordingly, devices connect in the licensed spectrum to a Primary Cell (PCell) and use Carrier Aggregation (CA) to benefit from additional transmission capacity in the unlicensed spectrum by connecting to one or more Secondary Cells (SCells) operating in the unlicensed spectrum. To reduce the changes required for aggregating licensed and unlicensed spectrum, the LTE frame timing in the PCell is simultaneously used in the SCell(s) (i.e., the PCell and the SCells are synchronized). In addition to LAA operation, it should be possible to run LTE fully on the unlicensed band without the support from the licensed band. This is referred to as LTE in the Unlicensed Band (LTE-U) Standalone or MulteFire.

Regulatory requirements, however, may not permit transmissions in the unlicensed spectrum without prior channel sensing. Because the unlicensed spectrum must be shared with other radios of similar or dissimilar wireless technologies, a so called Listen-Before-Talk (LBT) scheme needs to be applied. LBT is also referred to as a Clear Channel Assessment (CCA). Today, the unlicensed 5 GHz spectrum is mainly used by equipment implementing the IEEE 802.11 Wireless Local Area Network (WLAN) standard. This standard is known under its marketing brand "Wi-Fi."

The LBT procedure leads to uncertainty at the enhanced or evolved Node B (eNB) regarding whether or not the eNB will be able to transmit a downlink subframe(s). This leads to a corresponding uncertainty at the User Equipment device (UE) as to whether or not the UE actually has a subframe to decode. An analogous uncertainty exists in the uplink direction where the eNB is uncertain as to whether or not the UEs scheduled on the SCell are actually transmitted.

1 LTE

LTE uses Orthogonal Frequency Division Multiplexing (OFDM) in the downlink and Discrete Fourier Transform (DFT)-spread OFDM (also referred to as single-carrier Frequency Division Multiple Access (FDMA)) in the uplink. The basic LTE downlink physical resource can thus be seen as a time-frequency grid as illustrated in FIG. 1, where each

resource element corresponds to one OFDM subcarrier during one OFDM symbol interval. The uplink subframe has the same subcarrier spacing as the downlink, and the same number of Single Carrier FDMA (SC-FDMA) symbols in the time domain as OFDM symbols in the downlink.

In the time domain, LTE downlink transmissions are organized into 10 millisecond (ms) radio frames, where each radio frame consists of ten equally-sized subframes of length $T_{subframe}=1$ ms as shown in FIG. 2. For normal cyclic prefix, one subframe consists of 14 OFDM symbols. The duration of each symbol is approximately 71.4 microseconds (μ s).

Furthermore, the resource allocation in LTE is typically described in terms of resource blocks, where a resource block corresponds to one slot (0.5 ms) in the time domain and 12 contiguous subcarriers in the frequency domain. A pair of two adjacent resource blocks in the time direction (1.0 ms) is known as a resource block pair. Resource blocks are numbered in the frequency domain, starting with 0 from one end of the system bandwidth.

Downlink transmissions are dynamically scheduled, i.e., in each subframe the base station transmits control information about which terminals data is transmitted to and upon which resource blocks the data is transmitted, in the current downlink subframe. This control signaling is typically transmitted in the first 1, 2, 3, or 4 OFDM symbols in each subframe and the number $n=1, 2, 3$, or 4 is known as the Control Format Indicator (CFI). The downlink subframe also contains common reference symbols, which are known to the receiver and used for coherent demodulation of, e.g., the control information. A downlink system with CFI=3 OFDM symbols as control is illustrated in FIG. 3.

From LTE Release (Rel) 11 onwards, the above described resource assignments can also be scheduled on the enhanced Physical Downlink Control Channel (ePDCCH). For Rel-8 to Rel-10, only Physical Downlink Control Channel (PDCCH) is available.

The reference symbols shown in FIG. 3 are the Cell-Specific Reference Symbols (CRSs). The CRSs are used to support multiple functions including fine time and frequency synchronization and channel estimation for certain transmission modes.

1.1 PDCCH and ePDCCH

The PDCCH/ePDCCH is used to carry Downlink Control Information (DCI) such as scheduling decisions and power control commands. More specifically, the DCI includes the following:

- Downlink scheduling assignments, including Physical Downlink Shared Channel (PDSCH) resource indication, transport format, Hybrid Automatic Repeat Request (HARQ) information, and control information related to spatial multiplexing (if applicable). A downlink scheduling assignment also includes a command for power control of the Physical Uplink Control Channel (PUCCH) used for transmission of HARQ acknowledgements in response to downlink scheduling assignments.
- Uplink scheduling grants, including Physical Uplink Shared Channel (PUSCH) resource indication, transport format, and HARQ-related information. An uplink scheduling grant also includes a command for power control of the PUSCH.
- Power control commands for a set of terminals as a complement to the commands included in the scheduling assignments/grants.

One PDCCH/ePDCCH carries one DCI message containing one of the groups of information listed above. As multiple terminals can be scheduled simultaneously, and each terminal can be scheduled on both downlink and uplink simultaneously, there must be a possibility to transmit multiple scheduling messages within each subframe. Each scheduling message is transmitted on separate PDCCH/ePDCCH resources, and consequently there are typically multiple simultaneous PDCCH/ePDCCH transmissions within each subframe in each cell. Furthermore, to support different radio channel conditions, link adaptation can be used, where the code rate of the PDCCH/ePDCCH is selected by adapting the resource usage for the PDCCH/ePDCCH to match the radio channel conditions.

A discussion of the start symbol for PDSCH and ePDCCH within the subframe is now provided. The OFDM symbols in the first slot are numbered from 0 to 6. For transmissions modes 1-9, the starting OFDM symbol in the first slot of the subframe for ePDCCH can be configured by higher layer signaling and the same is used for the corresponding scheduled PDSCH. Both sets have the same ePDCCH starting symbol for these transmission modes. If not configured by higher layers, the start symbol for both PDSCH and ePDCCH is given by the CFI value signaled in Physical Control Format Indicator Channel (PCFICH).

Multiple OFDM starting symbol candidates can be achieved by configuring the UE in transmission mode 10 and having multiple ePDCCH physical resource block configuration sets. The starting OFDM symbol in the first slot in a subframe for ePDCCH can be configured independently for each ePDCCH set by higher layers to be a value from {1,2,3,4}. If a set is not higher layer configured to have a fixed start symbol, then the ePDCCH start symbol for this set follows the CFI value received in PCFICH.

1.2 CA

The LTE Rel-10 standard supports bandwidths larger than 20 Megahertz (MHz). One important requirement on LTE Rel-10 is to assure backward compatibility with LTE Rel-8. This should also include spectrum compatibility. That would imply that an LTE Rel-10 carrier, wider than 20 MHz, should appear as a number of LTE carriers to an LTE Rel-8 terminal. Each such carrier can be referred to as a Component Carrier (CC). In particular, for early LTE Rel-10 deployments, it can be expected that there will be a smaller number of LTE Rel-10-capable terminals compared to many LTE legacy terminals. Therefore, it is necessary to assure an efficient use of a wide carrier also for legacy terminals, i.e. that it is possible to implement carriers where legacy terminals can be scheduled in all parts of the wideband LTE Rel-10 carrier. One way to obtain this would be by means of CA. CA implies that an LTE Rel-10 terminal can receive multiple CCs, where the CCs have, or at least have the possibility to have, the same structure as an LTE Rel-8 carrier. CA is illustrated in FIG. 4. A CA-capable UE is assigned a PCell that is always activated, and one or more SCells that may be activated or deactivated dynamically.

The number of aggregated CCs as well as the bandwidth of the individual CCs may be different for uplink and downlink. A symmetric configuration refers to the case where the number of CCs in downlink is the same as the number of CCs in the uplink whereas an asymmetric configuration refers to the case where the number of CCs in the downlink is different than the number of CCs in the uplink. It is important to note that the number of CCs configured in a cell may be different from the number of CCs seen by a

terminal. A terminal may, for example, support more downlink CCs than uplink CCs, even though the cell is configured with the same number of uplink and downlink CCs.

In addition, a key feature of CA is the ability to perform cross-carrier scheduling. This mechanism allows a (e)PDCCH on one CC to schedule data transmissions on another CC by means of a 3-bit Carrier Indicator Field (CIF) inserted at the beginning of the (e)PDCCH messages. For data transmissions on a given CC, a UE expects to receive scheduling messages on the (e)PDCCH on just one CC—either the same CC or a different CC via cross-carrier scheduling. This mapping from (e)PDCCH to PDSCH is configured semi-statically.

1.3 LTE Measurements

The UE performs periodic cell search and Reference Signal Received Power (RSRP) and Reference Signal Received Quality (RSRQ) measurements in Radio Resource Control (RRC) Connected mode. The UE is responsible for detecting new neighbor cells, and for tracking and monitoring already detected cells. The detected cells and the associated measurement values are reported to the network. Reports to the network can be configured to be periodic or aperiodic based a particular event.

1.4 Rel-12 LTE Discovery Reference Signal (DRS)

To share the channel in the unlicensed spectrum, the cell cannot occupy the channel indefinitely. One of the existing mechanisms for interference avoidance and coordination among small cells is the SCell ON/OFF feature. In Rel-12 LTE, discovery signals were introduced to provide enhanced support for SCell ON/OFF operations. Specifically, these signals were introduced to handle potentially severe interference situations, particularly on the synchronization signals, resulting from dense deployment as well as to reduce UE inter-frequency measurement complexity.

The discovery signals in a DRS occasion are comprised of the Primary Synchronization Signal (PSS), the Secondary Synchronization Signal (SSS), CRS, and, when configured, the Channel State Information Reference Signals (CSI-RS). The PSS and SSS are used for coarse synchronization, when needed, and for cell identification. The CRS is used for fine time and frequency estimation and tracking and may also be used for cell validation, i.e., to confirm the cell Identity (ID) detected from the PSS and SSS. The CSI-RS is another signal that can be used in dense deployments for cell or transmission point identification. FIG. 5 shows the presence of these signals in a DRS occasion of length equal to two subframes and also shows the transmission of the signals over two different cells or transmission points.

The DRS occasion corresponding to transmissions from a particular cell may range in duration from one to five subframes for Frequency Division Duplexing (FDD) and two to five subframes for Time Division Duplexing (TDD). The subframe in which the SSS occurs marks the starting subframe of the DRS occasion. This subframe is either subframe 0 or subframe 5 in both FDD and TDD. In TDD, the PSS appears in subframe 1 and subframe 6 while in FDD the PSS appears in the same subframe as the SSS. The CRSs are transmitted in all downlink subframes and the Downlink Part of the Special Subframe (DwPTS) regions of special subframes.

The discovery signals should be useable by the UE for performing cell identification as well as RSRP and RSRQ measurements. The RSRP measurement definition based on

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discovery signals is the same as in prior releases of LTE. The Received Signal Strength Indicator (RSSI) measurement is defined as an average over all OFDM symbols in the downlink parts of the measured subframes within a DRS occasion. The RSRQ is then defined as $DRSRQ = N \times DRSRP / DRSSI$, where N is the number of physical resource blocks used in performing the measurement, DRSRP is the RSRP measurement based on the discovery signals, and DRSSI is the RSSI measured over the DRS occasion.

In LTE Rel-12, RSRP measurements based on the CRS and CSI-RS in the DRS occasions and RSRQ measurements based on the CRS in the DRS occasions have been defined. As stated earlier, discovery signals can be used in a small cell deployment where the cells are being turned off and on or in a general deployment where the on/off feature is not being used. For instance, discovery signals could be used to make RSRP measurements on different CSI-RS configurations in the DRS occasion being used within a cell, which enables the detection of different transmission points in a shared cell.

When measurements are made on the CSI-RS in a DRS occasion, the UE restricts its measurements to a list of candidates sent to the UE by the network via RRC signaling. Each candidate in this list contains a Physical Cell Identity (PCID), a Virtual Cell Identity (VCID), and a subframe offset indicating the duration, in number of subframes, between the subframe where the UE receives the CSI-RS and the subframe carrying the SSS. This information allows the UE to limit its search. The UE correlates to the received signal candidates indicated by the RRC signal and reports back any CSI-RS RSRP values that have been found to meet some reporting criterion, e.g., exceeding a threshold value.

When a UE is being served on multiple carrier frequencies via a PCell and one or more SCells, the UE needs to perform Radio Resource Management (RRM) measurements on other cells on the currently used carrier frequencies (i.e., intra-frequency measurements) as well as on cells on other carrier frequencies (i.e., inter-frequency measurements). Because the discovery signals are not transmitted continuously, the UE needs to be informed about the timing of the discovery signals so as to manage its search complexity. Furthermore, when a UE is being served on as many carrier frequencies as it is capable of supporting and inter-frequency RRM measurements need to be performed on a different carrier frequency that is not currently being used, the UE is assigned a measurement gap pattern. This gap pattern on a serving frequency allows the UE to retune its receiver for the serving frequency to the other frequency on which measurements are being performed. During this gap duration, the UE cannot be scheduled by the eNB on the current serving frequency. Knowledge of the timing of the discovery signals is especially important when the use of such measurement gaps is needed. Beyond mitigating UE complexity, this also ensures that the UE is not unavailable for scheduling for prolonged periods of time on the current serving frequencies (PCell or SCell).

The provision of such timing information is done via a Discovery Signal Measurement Timing Configuration (DMTC) that is signaled to the UE. The DMTC provides a window with a duration of 6 ms occurring with a certain periodicity and timing within which the UE may expect to receive discovery signals. The duration of 6 ms is the same as the measurement gap duration as currently defined in LTE and allows the measurement procedures at the UE for discovery signals to be harmonized regardless of the need for measurement gaps. Only one DMTC is provided per carrier frequency including the current serving frequencies.

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The UE can expect that the network will transmit discovery signals so that all cells that are intended to be discoverable on a carrier frequency transmit discovery signals within the DMTCs. Furthermore, when measurement gaps are needed, it is expected that the network will ensure sufficient overlap between the configured DMTCs and measurement gaps.

2 WLAN

In typical deployments of WLAN, Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) is used for medium access. This means that the channel is sensed to perform a CCA, and a transmission is initiated only if the channel is declared as Idle. In case the channel is declared as Busy, the transmission is essentially deferred until the channel is deemed to be Idle. When the range of several Access Points (APs) using the same frequency overlap, this means that all transmissions related to one AP might be deferred in case a transmission on the same frequency to or from another AP which is within range can be detected. Effectively, this means that if several APs are within range, they will have to share the channel in time, and the throughput for the individual APs may be severely degraded. A general illustration of the LBT mechanism is shown in FIG. 6.

3 LAA to Unlicensed Spectrum Using LTE

Up to now, the spectrum used by LTE is dedicated to LTE. This has the advantage that the LTE system does not need to take into account the coexistence issue and the spectrum efficiency can be maximized. However, the spectrum allocated to LTE is limited and, therefore, cannot meet the ever increasing demand for larger throughput from applications/services. Therefore, a new work item has been initiated in 3GPP on extending LTE to exploit unlicensed spectrum in addition to licensed spectrum. Unlicensed spectrum can, by definition, be simultaneously used by multiple different technologies. Therefore, LTE needs to consider the coexistence issue with other systems such as IEEE 802.11 (Wi-Fi) systems. Operating LTE in the same manner in unlicensed spectrum as in licensed spectrum can seriously degrade the performance of Wi-Fi as Wi-Fi will not transmit once it detects the channel is occupied.

Furthermore, one way to utilize the unlicensed spectrum reliably is to transmit essential control signals and channels on a licensed carrier. That is, as shown in FIG. 7, a UE is connected to a PCell in the licensed band and one or more SCells in the unlicensed band. In this application, a SCell in unlicensed spectrum is also referred to as a License Assisted (LA) SCell.

4 Standalone Operation in Unlicensed Spectrum Using LTE

Recently there have also been proposals to operate LTE in unlicensed spectrum without the aid of a licensed carrier. In such operation, the PCell will also operate on the unlicensed carrier and thus essential control signals and channels will also be subject to unmanaged interference and LBT.

LTE mobility, i.e. to maintain a connection while the UE is moving between different network nodes, is typically done on the PCell. When the PCell is operating in unlicensed spectrum, the signals used for mobility, which are typically PSS/SSS and CRS, are typically transmitted rather sparsely, e.g. in the DRS occasion. In addition, they are all subject to LBT, and thus their presence is not guaranteed.

Further, the rather dense system information broadcast messages that are typically transmitted on the PCell will also need to be transmitted more sparsely and under LBT constraints.

5 Network Synchronization

Network synchronization refers to the degree of time and frequency synchronization the network nodes have. The degree of synchronization typically varies from (1) tight, enough for advanced transmission techniques, which in today's LTE system is on the microsecond level, (2) coarse synchronization, which is enough for aligning, e.g., DRS occasions with DMTC windows and measurement gaps and is typically on the millisecond level, and (3) no synchronization.

6 Problem

Particularly when operating in the unlicensed spectrum, some cells may be synchronized while others may not. This presents new challenges with respect to DMTC. As such, there is a need for systems and methods that address these challenges.

SUMMARY

Systems and methods relating to Discovery Signal Measurement Timing Configuration (DMTC) are disclosed. In some embodiments, a method of operation of a radio access node in a cellular communications network comprises sending, to a wireless device, a DMTC for one of a group consisting of: (a) a frequency on which one or more asynchronous cells are operating, an asynchronous cell being a cell that is unsynchronized with a Primary Cell (PCell) of the wireless device, and (b) a Secondary Cell (SCell) configured for the wireless device such that the DMTC is a specific DMTC for the SCell. A DMTC configuration that is specific to a SCell provides improved measurement performance on the SCell because, e.g., the DMTC configuration can be specifically tailored to that SCell. A DMTC configuration for a frequency on which one or more asynchronous cells are operating provides improved measurement performance on that carrier.

In some embodiments, the DMTC is a DMTC for a SCell configured for the wireless device. Further, in some embodiments, sending the DMTC comprises sending, to the wireless device, a message that configures the SCell for the wireless device, the message comprising the DMTC for the SCell such that the DMTC is a specific DMTC for the SCell. In some embodiments, the message is an RRCConnection-Reconfiguration message.

In some embodiments, the DMTC is a DMTC for the frequency on which one or more asynchronous cells are operating. Further, in some embodiments, sending the DMTC comprises transmitting system information comprising an indication of whether one or more intra-frequency asynchronous cells are operating on the frequency and the DMTC for the frequency to be used by the wireless device if the indication is set to a value that indicates that one or more intra-frequency asynchronous cells are operating on the frequency. In some embodiments, the system information is a System Information Block type 3 (SIB3) information element. In some other embodiments, sending the DMTC comprises transmitting system information comprising an indication of whether one or more inter-frequency asynchronous cells are operating on the frequency and the

DMTC for the frequency to be used by the wireless device if the indication is set to a value that indicates that one or more inter-frequency asynchronous cells are operating on the frequency. In some embodiments, the system information is a SIB type 5 (SIB5) information element. In some other embodiments, sending the DMTC comprises transmitting a measurement object to the wireless device, the measurement object comprising an indication of whether one or more asynchronous cells are operating on the frequency and the DMTC for the frequency to be used by the wireless device if the indication is set to a value that indicates that one or more asynchronous cells are operating on the frequency.

In some embodiments, sending the DMTC comprises sending the DMTC and a second DMTC, the DMTC and the second DMTC being separate DMTCs and one of the DMTCs is associated with an asynchronous indication and the other DMTC is associated with a synchronous indication.

In some embodiments, the DMTC is a DMTC for the frequency on which one or more asynchronous cells are operating, and sending the DMTC comprises sending the DMTC together with an asynchronous indication that indicates whether any asynchronous cells are operating on the frequency and a second DMTC for the frequency together with an indication of whether any synchronous cells are operating on the frequency.

In some embodiments, the method further comprises determining whether to configure a cell as a SCell of the wireless device and, upon determining to configure the cell as a SCell of the wireless device, determining whether an asynchronous indication has been provided for a carrier frequency on which the cell operates. Sending the DMTC comprises, upon determining that the asynchronous indication has been provided, sending the DMTC for the cell in a message that adds the cell as a SCell of the wireless device.

Embodiments of a radio access node for a cellular communications network are also disclosed. In some embodiments, a radio access node for a cellular communications network comprises a processor and memory comprising instructions executable by the processor whereby the radio access node is operable to send, to a wireless device, a DMTC for one of a group consisting of: (a) a frequency on which one or more asynchronous cells are operating, an asynchronous cell being a cell that is unsynchronized with a PCell of the wireless device, and (b) a SCell configured for the wireless device such that the DMTC is a specific DMTC for the SCell.

In some embodiments, a radio access node for a cellular communications network is adapted to send, to a wireless device, a DMTC for one of a group consisting of: (a) a frequency on which one or more asynchronous cells are operating, an asynchronous cell being a cell that is unsynchronized with a PCell of the wireless device, and (b) a SCell configured for the wireless device such that the DMTC is a specific DMTC for the SCell. In some embodiments, the radio access node is further operable to operate according to any one of the embodiments of the method of operation of a radio access node disclosed herein.

In some embodiments, a radio access node for a cellular communications network comprises a sending module operable to send, to a wireless device, a DMTC for one of a group consisting of: (a) a frequency on which one or more asynchronous cells are operating, an asynchronous cell being a cell that is unsynchronized with a PCell of the wireless device, and (b) a SCell configured for the wireless device such that the DMTC is a specific DMTC for the SCell.

Embodiments of a method of operation of a wireless device in a cellular communications network are also disclosed. In some embodiments, a method of operation of a wireless device in a cellular communications network comprises receiving a DMTC for at least one of: (a) a frequency on which one or more asynchronous cells are operating, the one or more asynchronous cells being one or more cells that are unsynchronized with a PCell of the wireless device, and (b) a SCell configured for the wireless device such that the DMTC is a specific DMTC for the SCell. The method further comprises utilizing the DMTC.

In some embodiments, the DMTC is a DMTC for a SCell configured for the wireless device. Further, in some embodiments, receiving the DMTC comprises receiving a message that configures the SCell for the wireless device, the message comprising the DMTC for the SCell such that the DMTC is a specific DMTC for the SCell. In some embodiments, the message is an RRCConnectionReconfiguration message.

In some embodiments, the DMTC is a DMTC for a frequency on which one or more asynchronous cells are operating. Further, in some embodiments, receiving the DMTC comprises receiving system information comprising an indication of whether one or more intra-frequency asynchronous cells are operating on the frequency and the DMTC for the frequency to be used by the wireless device if the indication is set to a value that indicates that one or more intra-frequency asynchronous cells are operating on the frequency. In some embodiments, the system information is a SIB3 information element. In some other embodiments, receiving the DMTC comprises receiving system information comprising an indication of whether one or more inter-frequency asynchronous cells are operating on the frequency and the DMTC for the frequency to be used by the wireless device if the indication is set to a value that indicates that one or more inter-frequency asynchronous cells are operating on the frequency. In some embodiments, the system information is a SIB5 information element. In some other embodiments, receiving the DMTC comprises receiving a measurement object, the measurement object comprising an indication of whether one or more asynchronous cells are operating on the frequency and the DMTC for the frequency to be used by the wireless device if the indication is set to a value that indicates that one or more asynchronous cells are operating on the frequency.

In some embodiments, receiving the DMTC comprises receiving the DMTC and a second DMTC, the DMTC and the second DMTC being separate DMTCs and one of the DMTCs is associated with an asynchronous indication and the other DMTC is associated with a synchronous indication.

In some embodiments, the DMTC is a DMTC for the frequency on which one or more asynchronous cells are operating, and receiving the DMTC comprises receiving the DMTC together with an asynchronous indication that indicates whether any asynchronous cells are operating on the frequency and a second DMTC for the frequency together with an indication of whether any synchronous cells are operating on the frequency.

In some embodiments, utilizing the DMTC comprises determining that the message that configures the SCell for the wireless device comprises the DMTC for the SCell and, upon determining that the message comprises the DMTC for the SCell, prioritizing measurements according to the DMTC for the SCell. Further, in some embodiments, utilizing the DMTC further comprises determining whether an asynchronous indication has been received for a carrier

frequency on which the SCell operates and, upon determining that an asynchronous indication has been received, performing best effort measurements on neighbor cells on the carrier frequency on which the SCell operates.

Embodiments of a wireless device for a cellular communications network are also disclosed. In some embodiments, a wireless device for a cellular communications network comprises a transceiver, a processor, and memory comprising instructions executable by the processor whereby the wireless device is operable to receive a DMTC for at least one of: (a) a frequency on which one or more asynchronous cells are operating, the one or more asynchronous cells being one or more cells that are unsynchronized with a PCell of the wireless device, and utilize the DMTC, and (b) a SCell configured for the wireless device such that the DMTC is a specific DMTC for the SCell.

In some embodiments, a wireless device for a cellular communications network is adapted to receive a DMTC for at least one of: (a) a frequency on which one or more asynchronous cells are operating, the one or more asynchronous cells being one or more cells that are unsynchronized with a PCell of the wireless device, and (b) a SCell configured for the wireless device such that the DMTC is a specific DMTC for the SCell. The wireless device is further adapted to utilize the DMTC. In some embodiments, the wireless device is further adapted to operate according to any one of the embodiments of the method of operation of a wireless device disclosed herein.

In some embodiments, a wireless device for a cellular communications network comprises a receiving module and a utilizing module. The receiving module is operable to receive a DMTC for at least one of: (a) a frequency on which one or more asynchronous cells are operating, the one or more asynchronous cells being one or more cells that are unsynchronized with a PCell of the wireless device, and (b) a SCell configured for the wireless device such that the DMTC is a specific DMTC for the SCell. The utilizing module is operable to utilize the DMTC.

Those skilled in the art will appreciate the scope of the present disclosure and realize additional aspects thereof after reading the following detailed description of the embodiments in association with the accompanying drawing figures.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawing figures incorporated in and forming a part of this specification illustrate several aspects of the disclosure, and together with the description serve to explain the principles of the disclosure. In the drawings, like reference labels denote like features.

FIG. 1 illustrates a Long Term Evolution (LTE) downlink physical resource;

FIG. 2 illustrates an LTE time-domain structure;

FIG. 3 illustrates an example of an LTE downlink sub-frame;

FIG. 4 illustrates Carrier Aggregation (CA);

FIG. 5 illustrates one example of a discovery signal in LTE;

FIG. 6 illustrates Listen-Before-Talk (LBT);

FIG. 7 illustrates License Assisted Access (LAA) to unlicensed spectrum using LTE CA;

FIG. 8 illustrates one example of a cellular communications network (i.e., an LTE network in this example) in which embodiments of the present disclosure may be implemented;

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FIG. 9 illustrates a process by which a Discovery Signal Measurement Timing Configuration (DMTC) for a Secondary Cell (SCell) is provided to a wireless device in a message in which the SCell is added (i.e., configured) for the wireless device according to some embodiments of the present disclosure;

FIG. 10 illustrates a process by which a DMTC for asynchronous neighboring cells is provided to a wireless device in system information according to some embodiments of the present disclosure;

FIG. 11 illustrates a process by which a DMTC for asynchronous neighboring cells is provided to a wireless device in a measurement object according to some embodiments of the present disclosure;

FIG. 12 is a flow chart that illustrates the operation of a radio access node according to some embodiments of the present disclosure;

FIGS. 13 and 14 are flow charts that illustrate the operation of a wireless device according to some embodiments of the present disclosure;

FIGS. 15 and 16 are block diagram of some embodiments of a wireless device; and

FIGS. 17 through 19 are block diagrams of some embodiments of a radio access node.

DETAILED DESCRIPTION

The embodiments set forth below represent information to enable those skilled in the art to practice the embodiments and illustrate the best mode of practicing the embodiments. Upon reading the following description in light of the accompanying drawing figures, those skilled in the art will understand the concepts of the disclosure and will recognize applications of these concepts not particularly addressed herein. It should be understood that these concepts and applications fall within the scope of the disclosure and the accompanying claims.

The following description presents various embodiments of the disclosed subject matter. These embodiments are presented as teaching examples and are not to be construed as limiting the scope of the disclosed subject matter. For example, certain details of the described embodiments may be modified, omitted, or expanded upon without departing from the scope of the described subject matter.

As discussed above, in a conventional Third Generation Partnership Project (3GPP) Long Term Evolution (LTE) system, a single Discovery Signal Measurement Timing Configuration (DMTC) is provided for each carrier frequency. A problem arises, particularly when operating in the unlicensed spectrum (e.g., LTE in the Unlicensed Band (LTE-U) Standalone or MulteFire), when asynchronous cells (i.e., cells that are not synchronized with the Primary Cell (PCell) of the User Equipment device (UE)) are operating on a frequency for which the UE is configured to perform measurements such as, e.g., Radio Resource Management (RRM) measurements for mobility purposes. In this case, it is desirable to perform measurements on both synchronized and unsynchronized cells. However, the conventional DMTC per carrier frequency assumes synchronized cells and, as such, is unsuitable for unsynchronized cells. One way to address this issue is for the UE to “look everywhere” for the Discovery Reference Signals (DRSs) of unsynchronized cells. However, this has at least two problems. First, “looking everywhere” will result in the UE being active for longer periods of time and, consequently, a significant increase in power consumption. Second, the UE has no way of knowing whether there are unsynchronized

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cells on the carrier frequency and, as such, may expend valuable resources search for unsynchronized cells when there are none. At least some of the embodiments disclosed herein address these problems.

In certain embodiments the same DMTC configuration that is provided in an enhanced System Information Block (eSIB) or MulteFire System Information Block (SIB-MF) for the (primary) serving cell is also used for the (not yet configured) Secondary Cell(s) (SCell(s)) (“option 1”). Note that the terms “DMTC” and “DMTC configuration” are used interchangeably herein. In certain other embodiments, it is assumed that there are cells on the frequencies indicated in System Information Block type 5 (SIB5) that are synchronous with the PCell, and assume minimum periodicity for the DMTC periodicity, i.e. 40 milliseconds (ms), and maximum duration for the DMTC duration (10 ms) (“option 2”). In certain embodiments, the DMTC for the SCells is provided via dedicated signaling (“option 3”).

Certain embodiments are presented in recognition of shortcomings associated with alternative approaches, such as the following. Certain approaches provide the DMTC for a frequency, resulting in reduced measurement performance on the SCells, such that potential data rates on the SCells cannot be achieved.

Certain embodiments may also provide one or more benefits compared to conventional approaches. For example, in “option 1” embodiments, the information may be provided in a System Information Block (SIB) and in a Measurement Object (measObject) before SCells are added. Thus, the measurement performance for potential SCells can be improved leading to faster decisions for the enhanced or evolved Node B (eNB) as to whether to add another SCell for the UE or not. As another example, in “option 2” embodiments where it is assumed that there are cells on the frequencies indicated in SIB5 that are synchronous with the PCell, and minimum periodicity for the DMTC periodicity, i.e. 40 ms, and maximum duration for the DMTC duration (10 ms) are assumed, there may be better measurement performance if there are potential SCells and there could also be some battery savings if there are synchronized cells. As yet another example, “option 3” embodiments may exhibit improved measurement performance on the SCells, and potentially reduced UE power consumption if the DMTC of SCells is known and measurements on the same frequency have to be performed less often.

For option 1 and 2, the UE assumes that there are cell(s) on the carrier frequencies indicated in SIB5 that may potentially be configured as SCell(s), even if the async bit is set to true. In other words, for example, the SIB5 may include an async bit that, if set, indicates that there are cells on the corresponding frequency that are asynchronous.

For option 1, there are different approaches:

1a) The field description for the servCellDMTC in the eSIB/SIB-MF could be updated to apply to the PCell and all cells that can be configured as SCells, e.g. cells that are potentially operated by, e.g., the serving eNB (could also be inter-node Carrier Aggregation (CA) if the cells are tightly synchronized and the operating eNBs have an interface for fast data exchange).

1b) There could be an additional bit indicating in the SIB-MF that the servCellDMTC shall be used for the SCells.

1c) There could be an additional bit in SIB5 indicating that the eNB operates synchronous cells on the carrier frequency indicated by (dl-)CarrierFreq, e.g. sync-NeighCells.

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1d) There could be an additional bit in the measObject indicating that the eNB operates synchronous cells on the carrier frequency indicated by (dl-)CarrierFreq, e.g. syncNeighCells. For options 1c and 1d, the eNB could provide the UE with accurate DMTC configuration.

1e) There are two separate DMTC configurations, one together with the async indication (where the DMTC could be empty), and one together with the sync indication. Notably, these two indications may be implemented in any suitable manner. As will be appreciated by one of skill in the art, the two indications may be implemented as different parameters (e.g., an async parameter and a sync parameter) or as a single parameter. As an example, the two indications may be implemented as a single async parameter where the async parameter operates as both an async indication and a sync indication.

One example for SIB5 and, e.g., measObject:

[[OP	asyncNeighCells-MF	BOOLEAN	OPTIONAL	-- Need
	neighborCellDMTC-MF	MeasDS-Config-MF	OPTIONAL	-- Need
OP]]				

This example for SIB5 and, e.g., measObject may be used to provide an async indication (referred to as asyncNeighCells-MF) that, if set, indicates that there are asynchronous cells on the respective frequency. If the async indication is set to a value that indicates that one or more asynchronous neighbor cells are operating on the frequency, then the DMTC (neighborCellDMTC-MF) is the DMTC for the asynchronous neighbor cells (i.e., cells that are not serving cells of the UE that operate on the respective frequency identified by SIB5 or measObject).

Example for options 1c/1d in SIB5 and, e.g., measObject:

[[OP	asyncNeighCells-MF	BOOLEAN	OPTIONAL	-- Need
	syncNeighCell-MF	BOOLEAN	OPTIONAL	-- Need
OP]]	neighborCellDMTC-MF	MeasDS-Config-MF	OPTIONAL	-- Need

This example is for SIB5 and, e.g., measObject where there is an additional indication of whether there are any synchronous cells on the respective frequency.

Example for option 1e in SIB5 and, e.g., measObject:

[[Need OP	asyncNeighCellInfo-MF	SEQUENCE {		
	asyncNeighCells-MF	ENUMERATED{true},		
Need OP }],	asyncNeighCellDMTC-MF	MeasDS-Config-MF	OPTIONAL	--
			OPTIONAL	--
Need OP]]	syncNeighCellDMTC-MF	MeasDS-Config-MF	OPTIONAL	--

This example is for SIB5 and, e.g., measObject where the SIB5 or measurement object includes both: (a) a DMTC for asynchronous cells (asyncNeighCellDMTC-MF) together with the async indication (asyncNeighCells-MF) and (b) a separate DMTC for synchronous cells (syncNeighCellD-

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MTC-MF). While not illustrated in this example, as discussed above, the DMTC for synchronous cells may be provided together with a sync indication, i.e., an indication of whether there are any synchronous cells on the respective frequency.

For the non-synchronized neighbor cells, the DMTC is only provided if available.

For option 2, a sync bit could also be added to SIB5 and the measObject to make the UE aware that there are unsynchronized cells, synchronized cells, or even both on the carrier frequency identified by (dl-)CarrierFreq.

Option 3 can be combined with option 1 or option 2, respectively.

The embodiments described herein may be implemented in any appropriate type of communication system supporting any suitable communication standards and using any suitable components. As one example, certain embodiments may be implemented in an LTE network, such as that illustrated in FIG. 8. Referring to FIG. 8, a communication network 10 comprises a plurality of wireless communication devices 12 (e.g., UEs such as, but not limited to, regular UEs, Machine Type Communication (MTC)/Machine-to-Machine (M2M) UEs, or the like) and a plurality of radio access nodes 14 (e.g., eNBs or other base stations). The wireless communication devices 12 are also referred to herein as wireless devices 12. Further, it is to be understood that the UEs referred to herein are one embodiment of the wireless devices 12. The communication network 10 is organized into cells 16, which are connected to a core network 18 via the corresponding radio access nodes 14. The radio access nodes 14 are capable of communicating with the wireless communication devices 12 along with any additional elements suitable to support communication between wireless communication devices or between a wireless communication device and another communication device (such as a landline telephone).

As discussed above, there may be multiple levels of DMTC. Specifically, at one level, the network (e.g., the radio access node 14, which may be, e.g., an eNB) provides a DMTC to the wireless device 12 (e.g., UE) that is specific for a configured (i.e., an added) SCell of the wireless device 12. In this case, the DMTC may be provided via dedicated signaling such as, for example, an RRCConnectionReconfiguration message in which the SCell is configured for the wireless device 12. By being specifically for the SCell, the DMTC may be narrowly tailored for that particular SCell, which in turn improves performance of the wireless device 12. At another level, the network (e.g., radio access node 14) provides a DMTC to the wireless device 12 for synchronous cells on a particular carrier frequency. In this case, the DMTC may be included in system information (e.g., SIB3

or SIB5) or included in a measurement object used to configure the wireless device 12 to perform measurements on that carrier frequency. Since the cells are synchronous, the DMTC configuration may be tailored to synchronous cells (i.e., does not need to accommodate asynchronous

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cells), which in turn improves performance. At yet another level, the network (e.g., radio access node **14**) provides a DMTC to the wireless device **12** for asynchronous cells on a particular carrier frequency. In this case, the DMTC may be included in system information (e.g., SIB3 or SIB5) or included in a measurement object used to configure the wireless device **12** to perform measurements on that carrier frequency. Since the cells are asynchronous, the DMTC configuration may be tailored to asynchronous cells (e.g., longer DMTC duration or window than for synchronous cells) while still keeping the wireless device **12** from having to, e.g., search in all possible time resources for discovery signals from the asynchronous cells. Further, in some embodiments, the async indication and/or the sync indication inform the wireless device **12** as to whether there are asynchronous cells and/or synchronous cells on the respective carrier frequency. This further enables the wireless device **12** to use appropriate DMTC.

In this regard, FIG. 9 illustrates the operation of the radio access node **14** and the wireless device **12** according to some embodiments of the present disclosure in which the radio access node **14** provides a DMTC to the wireless device **12** for a SCell configured (i.e., added) for the wireless device **12** via dedicated signaling. As illustrated, in this example, the radio access node **14** sends an RRCConnectionReconfigu-

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ration message to the wireless device **12**, where the RRC-ConnectionReconfiguration message configures one or more SCells for the wireless device **12** and includes, for each configured SCell, a DMTC specifically for the configured SCell (step **100**). Note that the RRCConnectionReconfiguration message is only one example of dedicated signaling. Other types of dedicated signaling may alternatively be used. The wireless device **12** utilizes the DMTC(s) for the configured, or added, SCell(s) (step **102**). The wireless device **12** may use the DMTCs to perform measurements such as RRM measurements on the configured SCell(s).

Below, example ASN.1 coded for dedicated Radio Resource Control (RRC) signaling and a new RRCConnectionReconfiguration message including the SCell DMTC are provided. Portions relating to the DMTC for the SCell are in bold and italicized.

The RRCConnectionReconfiguration message is the command to modify an RRC connection. It may convey information for measurement configuration, mobility control, radio resource configuration (including resource blocks, Medium Access Control (MAC) main configuration, and physical channel configuration) including any associated dedicated Non-Access Stratum (NAS) information and security configuration.

ASN.1 Code for Dedicated RRC Signaling (from 3GPP Technical Specification (TS) 36.331):

```

RRCConnectionReconfiguration-v1020-IEs ::= SEQUENCE {
    sCellToReleaseList-r10    SCellToReleaseList-r10        OPTIONAL, --
    Need ON
    sCellToAddModList-r10    SCellToAddModList-r10        OPTIONAL, --
    Need ON
    nonCriticalExtension      RRCConnectionReconfiguration-v1130-IEs  OPTIONAL
}

```

```

RRCConnectionReconfiguration message
-- ASN1START
RRCConnectionReconfiguration ::= SEQUENCE {
    rrc-TransactionIdentifier    RRC-TransactionIdentifier,
    criticalExtensions            CHOICE {
        c1                       CHOICE {
            rrcConnectionReconfiguration-r8    RRCConnectionReconfiguration-r8-IEs,
            spare7 NULL,
            spare6 NULL, spare5 NULL, spare4 NULL,
            spare3 NULL, spare2 NULL, spare1 NULL
        },
        criticalExtensionsFuture    SEQUENCE { }
    }
}
RRCConnectionReconfiguration-r8-IEs ::= SEQUENCE {
    measConfig                    MeasConfig                                OPTIONAL, --
    Need ON
    mobilityControlInfo           MobilityControlInfo                      OPTIONAL, --
    Cond HO
    dedicatedInfoNASList          SEQUENCE (SIZE (1..maxDRB)) OF
                                    DedicatedInfoNAS                        OPTIONAL, --
    Cond nonHO
    radioResourceConfigDedicated  RadioResourceConfigDedicated            OPTIONAL, -- Cond
    HO-toEUTRA
    securityConfigHO              SecurityConfigHO                        OPTIONAL, --
    Cond HO
    nonCriticalExtension           RRCConnectionReconfiguration-v890-IEs    OPTIONAL
}
RRCConnectionReconfiguration-v890-IEs ::= SEQUENCE {
    lateNonCriticalExtension       OCTET STRING (CONTAINING
RRCConnectionReconfiguration-v8m0-IEs)  OPTIONAL,
    nonCriticalExtension           RRCConnectionReconfiguration-v920-IEs    OPTIONAL
}
-- Late non-critical extensions:
RRCConnectionReconfiguration-v8m0-IEs ::= SEQUENCE {
    -- Following field is only for pre REL-10 late non-critical extensions

```

-continued

RRCConnectionReconfiguration message		
lateNonCriticalExtension	OCTET STRING	OPTIONAL,
nonCriticalExtension	RRCConnectionReconfiguration-v10i0-IEs	
OPTIONAL		
}		
RRCConnectionReconfiguration-v10i0-IEs ::= SEQUENCE {		
antennaInfoDedicatedPCell-v10i0	AntennaInfoDedicated-v10i0	OPTIONAL, -
- Need ON		
-- Following field is only for late non-critical extensions from REL-10		
nonCriticalExtension	SEQUENCE { }	OPTIONAL
}		
-- Regular non-critical extensions:		
RRCConnectionReconfiguration-v920-IEs ::= SEQUENCE {		
otherConfig-r9	OtherConfig-r9	OPTIONAL, --
Need ON		
fullConfig-r9	ENUMERATED {true}	OPTIONAL, --
Cond HO-Reestab		
nonCriticalExtension	RRCConnectionReconfiguration-v10i0-IEs	OPTIONAL
}		
RRCConnectionReconfiguration-v1020-IEs ::= SEQUENCE {		
sCellToReleaseList-r10	SCellToReleaseList-r10	OPTIONAL, --
Need ON		
sCellToAddModList-r10	SCellToAddModList-r10	OPTIONAL, --
Need ON		
nonCriticalExtension	RRCConnectionReconfiguration-v1130-IEs	OPTIONAL
}		
RRCConnectionReconfiguration-v1130-IEs ::= SEQUENCE {		
systemInformationBlockType1Dedicated-r11	OCTET STRING (CONTAINING	
SystemInformationBlockType1)		OPTIONAL,
-- Need ON		
nonCriticalExtension	RRCConnectionReconfiguration-v1250-IEs	OPTIONAL
}		
RRCConnectionReconfiguration-v1250-IEs ::= SEQUENCE {		
wlan-OffloadInfo-r12	CHOICE {	
release	NULL,	
setup	SEQUENCE {	
wlan-OffloadConfigDedicated-r12	WLAN-OffloadConfig-r12,	
t350-r12	ENUMERATED (min5, min10, min20,	
min30, min60,	min120, min180, spare1}	OPTIONAL -
- Need OR		
}		
}		OPTIONAL, -
- Need ON		
scg-Configuration-r12	SCG-Configuration-r12	OPTIONAL, -- Cond
nonFullConfig		
sl-SyncTxControl-r12	SL-SyncTxControl-r12	OPTIONAL, --
Need ON		
sl-DiscConfig-r12	SL-DiscConfig-r12	OPTIONAL, --
Need ON		
sl-CommConfig-r12	SL-CommConfig-r12	OPTIONAL, --
Need ON		
nonCriticalExtension	RRCConnectionReconfiguration-v1310-IEs	OPTIONAL
}		
RRCConnectionReconfiguration-v1310-IEs ::= SEQUENCE {		
sCellToReleaseListExt-r13	SCellToReleaseListExt-r13	OPTIONAL, --
Need ON		
sCellToAddModListExt-r13	SCellToAddModListExt-r13	OPTIONAL, --
Need ON		
lwa-Configuration-r13	LWA-Configuration-r13	OPTIONAL, --
Need ON		
lwip-Configuration-r13	LWIP-Configuration-r13	OPTIONAL, --
Need ON		
steeringCommandWLAN-r13	CHOICE {	
release	NULL,	
setup	SEQUENCE {	
command	CHOICE {	
steerToWLAN-r13	WLAN-Id-List-r12,	
steerToLTE-r13	NULL	
},		
...		
}		
}		OPTIONAL, --
Need ON		
nonCriticalExtension	RRCConnectionReconfiguration-MF-IEs	
OPTIONAL		
}		
RRCConnectionReconfiguration-MF-IEs ::= SEQUENCE {		

-continued

RRCConnectionReconfiguration message		
<i>sCellToReleaseListExt-MF</i> <i>Need ON</i>	<i>SCellToReleaseListExt-r13</i>	<i>OPTIONAL, --</i>
<i>sCellToAddModListExt-MF</i> <i>Need ON</i>	<i>SCellToAddModListExt-MF</i>	<i>OPTIONAL, --</i>
<i>lwa-Configuration-MF</i> <i>Need ON</i>	<i>LWA-Configuration-r13</i>	<i>OPTIONAL, --</i>
<i>lwip-Configuration-MF</i> <i>Need ON</i>	<i>LWIP-Configuration-r13</i>	<i>OPTIONAL, --</i>
<i>steeringCommandWLAN-MF</i> <i>release</i> <i>setup</i> <i>command</i> <i>steerToWLAN-MF</i> <i>steerToLTE-MF</i> }, ... }	<i>CHOICE {</i> <i>NULL,</i> <i>SEQUENCE {</i> <i>CHOICE {</i> <i>WLAN-Id-List-r12,</i> <i>NULL</i> }, }	
<i>nonCriticalExtension</i> }	<i>SEQUENCE {}</i>	<i>OPTIONAL, --</i> <i>OPTIONAL</i>
SL-SyncTxControl-r12 ::= networkControlledSyncTx-r12 - Need OP }	SEQUENCE { ENUMERATED {on, off}	OPTIONAL -
PSCellToAddMod-r12 ::= sCellIndex-r12 cellIdentification-r12 physCellId-r12 dl-CarrierFreq-r12 }	SEQUENCE { SCellIndex-r10, SEQUENCE { PhysCellId, ARFCN-ValueEUTRA-r9	OPTIONAL,
Cond SCellAdd radioResourceConfigCommonPSCell-r12 -- Cond SCellAdd radioResourceConfigDedicatedPSCell-r12 OPTIONAL, -- Cond SCellAdd2 ... , [[antennaInfoDedicatedPSCell-v1280 - Need ON]], [[sCellIndex-r13]] }	RadioResourceConfigCommonPSCell-r12 RadioResourceConfigDedicatedPSCell-r12 AntennaInfoDedicated-v10i0 SCellIndex-r13	OPTIONAL, OPTIONAL - OPTIONAL -- Need ON
PowerCoordinationInfo-r12 ::= SEQUENCE { p-MeNB-r12 p-SeNB-r12 powerControlMode-r12 }	INTEGER (1..16), INTEGER (1..16), INTEGER (1..2)	
SCellToAddModList-r10 ::= SCellToAddModListExt-r13 ::= <i>SCellToAddModListExt-MF ::=SEQUENCE (SIZE (1..maxSCell-r13))OF SCellToAddModExt-MF</i>	SEQUENCE (SIZE (1..maxSCell-r10)) OF SCellToAddMod-r10 SEQUENCE (SIZE (1..maxSCell-r13)) OF SCellToAddModExt-r13	
SCellToAddMod-r10 ::= sCellIndex-r10 cellIdentification-r10 physCellId-r10 dl-CarrierFreq-r10 }	SEQUENCE { SCellIndex-r10, SEQUENCE { PhysCellId, ARFCN-ValueEUTRA	OPTIONAL, -- Cond
SCellAdd radioResourceConfigCommonSCell-r10 -- Cond SCellAdd radioResourceConfigDedicatedSCell-r10 OPTIONAL, -- Cond SCellAdd2 ... , [[dl-CarrierFreq-v1090 EARFCN-max]], [[antennaInfoDedicatedSCell-v10i0 Need ON]] <i>// measDS-Config-MF</i> <i>Need ON</i> <i>//</i> }	RadioResourceConfigCommonSCell-r10 RadioResourceConfigDedicatedSCell-r10 ARFCN-ValueEUTRA-v9e0 AntennaInfoDedicated-v10i0 <i>MeasDS-Config-MF</i>	OPTIONAL, OPTIONAL -- <i>OPTIONAL --</i>
SCellToAddModExt-r13 ::= sCellIndex-r13 cellIdentification-r13 physCellId-r13	SEQUENCE { SCellIndex-r13, SEQUENCE { PhysCellId,	

-continued

RRCConnectionReconfiguration message			
dl-CarrierFreq-r13	ARFCN-ValueEUTRA-r9		OPTIONAL, -- Cond
SCellAdd			
radioResourceConfigCommonSCell-r13	RadioResourceConfigCommonSCell-r10		OPTIONAL,
-- Cond SCellAdd			
radioResourceConfigDedicatedSCell-r13	RadioResourceConfigDedicatedSCell-r10		
OPTIONAL, -- Cond SCellAdd2			
antennaInfoDedicatedSCell-r13	AntennaInfoDedicated-v10i0		OPTIONAL -
- Need ON}			
SCellToAddModExt-MF ::=	SEQUENCE {		
sCellIndex-MF	SCellIndex-r13,		
cellIdentification-MF	SEQUENCE {		
physCellId-MF	PhysCellId,		
dl-CarrierFreq-MF	ARFCN-ValueEUTRA-r9		
}	OPTIONAL, --Cond		
SCellAdd			
radioResourceConfigCommonSCell-MF	RadioResourceConfigCommonScell-r10		
OPTIONAL,			
--Cond SCellAdd			
radioResourceConfigDedicatedSCell-MF	RadioResourceConfigDedicatedSCell-r10		
OPTIONAL,			
--Cond SCellAdd2			
antennaInfoForDedicatedSCell-MF	AntennaInfoDedicated-y10i0		OPTIONAL -
- Need ON			
measDS-Config-MF	MeasDS-Config-MF		OPTIONAL -
- Need ON			
...			
}			
SCellToReleaseList-r10 ::=	SEQUENCE (SIZE (1..maxSCell-r10)) OF SCellIndex-r10		
SCellToReleaseListExt-r13 ::=	SEQUENCE (SIZE (1..maxSCell-r13)) OF SCellIndex-		
r13			
SCG-Configuration-r12 ::=	CHOICE {		
release	NULL,		
setup	SEQUENCE {		
scg-ConfigPartMCG-r12	SEQUENCE {		
scg-Counter-r12	INTEGER (0.. 65535)		OPTIONAL, -
- Need ON			
powerCoordinationInfo-r12	PowerCoordinationInfo-r12		OPTIONAL, -
- Need ON			
...			
}			OPTIONAL, --
Need ON			
scg-ConfigPartSCG-r12	SCG-ConfigPartSCG-r12		OPTIONAL --
Need ON			
}			
}			
SCG-ConfigPartSCG-r12 ::=	SEQUENCE {		
radioResourceConfigDedicatedSCG-r12	RadioResourceConfigDedicatedSCG-r12		OPTIONAL, -
- Need ON			
sCellToReleaseListSCG-r12	SCellToReleaseList-r10		OPTIONAL, -- Need
ON			
pSCellToAddMod-r12	PSCellToAddMod-r12		OPTIONAL, -- Need
ON			
sCellToAddModListSCG-r12	SCellToAddModList-r10		OPTIONAL, -- Need
ON			
mobilityControlInfoSCG-r12	MobilityControlInfoSCG-r12		OPTIONAL, -- Need
ON			
...			
[[
sCellToReleaseListSCG-Ext-r13	SCellToReleaseListExt-r13		OPTIONAL, -
- Need ON			
sCellToAddModListSCG-Ext-r13	SCellToAddModListExt-r13		OPTIONAL -
- Need ON			
]]			
}			
SecurityConfigHO ::=	SEQUENCE {		
handoverType	CHOICE {		
intraLTE	SEQUENCE {		
securityAlgorithmConfig	SecurityAlgorithmConfig		OPTIONAL, -
- Cond fullConfig			
keyChangeIndicator	BOOLEAN,		
nextHopChainingCount	NextHopChainingCount		
}			
interRAT	SEQUENCE {		
securityAlgorithmConfig	SecurityAlgorithmConfig,		
nas-SecurityParamToEUTRA	OCTET STRING (SIZE(6))		
}			

-continued

RRCConnectionReconfiguration message	
<pre> }, ... } -- ASN1STOP </pre>	

RRCConnectionReconfiguration field descriptions		-continued	
dedicatedInfoNASList		sCellToAddModList, sCellToAddModListExt	
This field is used to transfer UE specific NAS layer information between the network and the UE. The RRC layer is transparent for each PDU in the list.		15 Indicates the SCell to be added or modified. Indexes 1..7 can be assigned using either sCellToAddModList or sCellToAddModListExt.	
fullConfig		sCellToAddModListSCG	
Indicates the full configuration option is applicable for the RRC Connection Reconfiguration message.		Indicates the SCG cell to be added or modified. The field is used for SCG cells other than the PSCell (which is added/modified by field	
keyChangeIndicator		20 pSCellToAddMod).	
true is used only in an intra-cell handover when a K_{eNB} key is derived from a K_{ASME} key taken into use through the latest successful NAS SMC procedure, as described in TS 33.401 [32] for K_{eNB} re-keying, false is used in an intra-LTE handover when the new K_{eNB} key is obtained from the current K_{eNB} key or from the NH as described in TS 33.401 [32].		sCellToReleaseListSCG	
lwa-Configuration		Indicates the SCG cell to be released. The field is also used to release the PSCell e.g. upon change of PSCell, upon system information change for the PSCell.	
This field is used to provide parameters for LWA configuration.		25 scg-Counter	
lwip-Configuration		A counter used upon initial configuration of SCG security as well as upon refresh of S- K_{eNB} . E-UTRAN includes the field upon SCG change when one or more SCG DRBs are configured. Otherwise E-UTRAN does not include the field.	
This field is used to provide parameters for LWIP configuration.		30 steeringCommandWLAN	
measDS-Config		WLAN traffic steering command as specified in 5.6.16.2.	
Parameters applicable to discovery signals measurement for the SCell indicated by the SCellIndex on the carrier frequency indicated by dl-CarrierFreq. Any other DMTC configuration provided for the carrier frequency indicated by dl-CarrierFreq shall still apply for the neighbor cells on that carrier frequency.		t350	
nas-securityParamToEUTRA		Timer T350 as described in section 7.3. Value minN corresponds to N minutes.	
This field is used to transfer UE specific NAS layer information between the network and the UE. The RRC layer is transparent for this field, although it affects activation of AS- security after inter-RAT handover to E-UTRA. The content is defined in TS 24.301.		35	
networkControlledSyncTx			
This field indicates whether the UE shall transmit synchronisation information (i.e. become synchronisation source). Value On indicates the UE to transmit synchronisation information while value Off indicates the UE to not transmit such information.			
nextHopChainingCount			
Parameter NCC: See TS 33.401 [32]			
p-MeNB			
Indicates the guaranteed power for the MeNB, as specified in 36.213 [23]. The value N corresponds to $N - 1$ in TS 36.213 [23].			
powerControlMode			
Indicates the power control mode used in DC. Value 1 corresponds to DC power control mode 1 and value 2 indicates DC power control mode 2, as specified in 36.213 [23].			
p-SeNB			
Indicates the guaranteed power for the SeNB as specified in 36.213 [23, Table 5.1.4.2-1]. The value N corresponds to $N - 1$ in TS 36.213 [23].			
sCellIndex			
In case of DC, the SCellIndex is unique within the scope of the UE i.e. an SCG cell can not use the same value as used for an MCG cell. For pSCellToAddMod, if sCellIndex-r13 is present the UE shall ignore sCellIndex-r12. sCellIndex-r13 in sCellToAddModListExt-r13 shall not have same values as sCellIndex-r10 in sCellToAddModList-r10.			

FIG. 10 illustrates the operation of the radio access node 14 and the wireless device 12 according to some embodiments of the present disclosure in which a DMTC(s) is provided to the wireless device 12 for a carrier frequency(ies) together with a respective async indication(s) within system information. As illustrated, the radio access node 14 sends a SIB (e.g., SIB3 and/or SIB5) to the wireless device 12 where the SIB includes: (a) an async indication(s) for a respective downlink carrier frequency(ies) and (b) for each downlink carrier frequency, a DMTC configuration to be used if the async indication for the downlink carrier frequency is set to a value that indicates that one or more asynchronous cells are operating on the downlink carrier frequency (i.e., indicates that there are asynchronous cell(s) on the downlink carrier frequency) (step 200). The wireless device 12 utilizes the DMTC(s) for the carrier frequency(ies) (step 202). The wireless device 12 may use the DMTC(s) to perform measurements such as RRM measurements on the asynchronous cells on the respective carrier frequency(ies) indicated in the SIB.

Below, examples of SIB3 and SIB5 including the async indication and DMTC configuration are provided. Note that, as discussed above, SIB3 and/or SIB5 may be further modified to include, for each downlink carrier frequency specified in the SIB3/SIB5, a separate DMTC configuration for synchronous cells on the downlink carrier frequency and, in some embodiments, a sync indication that, if set, indicates that there are synchronous cells on the downlink carrier frequency (and thus that the wireless device 12 should use the DMTC provided for synchronous cells to, e.g., perform

RRM measurements). In the example below, portions related to DMTC and async indication are bolded and italicized.

The Information Element (IE) SystemInformationBlock-Type3 contains cell re-selection information common for intra-frequency, inter-frequency, and/or inter-Radio Access

Technology (RAT) cell re-selection (i.e., applicable for more than one type of cell re-selection but not necessarily all) as well as intra-frequency cell re-selection information other than neighboring cell related information.

SystemInformationBlockType3 information element			
-- ASN1START			
SystemInformationBlockType3 ::=	SEQUENCE {		
cellReselectionInfoCommon	SEQUENCE {		
q-Hyst	ENUMERATED {		
	dB0, dB1, dB2, dB3, dB4, dB5, dB6, dB8,		
dB10,			
	dB12, dB14, dB16, dB18, dB20, dB22,		
dB24},			
speedStateReselectionPars	SEQUENCE {		
mobilityStateParameters	MobilityStateParameters,		
q-HystSF	SEQUENCE {		
sf-Medium	ENUMERATED {		
	dB-6, dB-4, dB-2, dB0},		
	ENUMERATED {		
sf-High	dB-6, dB-4, dB-2, dB0}		
	}		
}			OPTIONAL -
- Need OP			
},			
cellReselectionServingFreqInfo	SEQUENCE {		
s-NonIntraSearch	ReselectionThreshold	OPTIONAL,	-
- Need OP			
threshServingLow	ReselectionThreshold,		
cellReselectionPriority	CellReselectionPriority		
}			
intraFreqCellReselectionInfo	SEQUENCE {		
q-RxLevMin	Q-RxLevMin,		
p-Max	P-Max	OPTIONAL,	-
- Need OP			
s-IntraSearch	ReselectionThreshold	OPTIONAL,	-
- Need OP			
allowedMeasBandwidth	AllowedMeasBandwidth	OPTIONAL,	-
- Need OP			
presenceAntennaPort1	PresenceAntennaPort1,		
neighCellConfig	NeighCellConfig,		
t-ReselectionEUTRA	T-Reselection,		
t-ReselectionEUTRA-SF	SpeedStateScaleFactors	OPTIONAL	-
- Need OP			
},			
...			
lateNonCriticalExtension	OCTET STRING (CONTAINING		
SystemInformationBlockType3-v10j0-IEs)	OPTIONAL,		
[[s-IntraSearch-v920	SEQUENCE {		
s-IntraSearchP-r9	ReselectionThreshold,		
s-IntraSearchQ-r9	ReselectionThresholdQ-r9	OPTIONAL,	-
}			
- Need OP			
s-NonIntraSearch-v920	SEQUENCE {		
s-NonIntraSearchP-r9	ReselectionThreshold,		
s-NonIntraSearchQ-r9	ReselectionThresholdQ-r9	OPTIONAL,	-
}			
- Need OP			
q-QualMin-r9	Q-QualMin-r9	OPTIONAL,	-
- Need OP			
threshServingLowQ-r9	ReselectionThresholdQ-r9	OPTIONAL	-
- Need OP			
]],			
[[q-QualMinWB-r11	Q-QualMin-r9	OPTIONAL	--
Cond WB-RSRQ			
]],			
[[q-QualMinRSRQ-OnAllSymbols-r12	Q-QualMin-r9	OPTIONAL	
-- Cond RSRQ			
]],			
[[cellReselectionServingFreqInfo-v1310	CellReselectionServingFreqInfo-v1310		
OPTIONAL, -- Need OP			
redistributionServingInfo-r13	RedistributionServingInfo-r13	OPTIONAL,	-
-Need OR			
cellSelectionInfoCE-r13	CellSelectionInfoCE-r13	OPTIONAL,	
-- Need OP			
t-ReselectionEUTRA-CE-r13	T-ReselectionEUTRA-CE-r13	OPTIONAL	
-- Need OP			
]],			

-continued

SystemInformationBlockType3 information element		
// intraFreqAsyncNeighCells-MF - Need OP	BOOLEAN	OPTIONAL, -
intraFreqDMTC-MF - Need OP	MeasDS-Config-MF	OPTIONAL, -
- Need OP		
}		
RedistributionServingInfo-r13 ::=	SEQUENCE {	
redistributionFactorServing-r13	INTEGER(0..10),	
redistributionFactorCell-r13	ENUMERATED {true}	OPTIONAL, --
Need OP		
t360-r13	ENUMERATED {min4, min8, min16, min32, infinity, spare3,spare2,spare1},	
redistrOnPagingOnly-r13	ENUMERATED {true}	OPTIONAL --Need OP
}		
CellReselectionServingFreqInfo-v1310 ::=	SEQUENCE {	
cellReselectionSubPriority-r13	CellReselectionSubPriority-r13	
}		
-- Late non critical extensions		
SystemInformationBlockType3-v10j0-IEs ::=	SEQUENCE {	
freqBandInfo-r10	NS-PmaxList-r10	OPTIONAL, -- Need
OR		
multiBandInfoList-v10j0	MultiBandInfoList-v10j0	OPTIONAL, -- Need
OR		
nonCriticalExtension	SEQUENCE { }	OPTIONAL
}		
-- ASN1STOP		

-continued

SystemInformationBlockType3 field descriptions		SystemInformationBlockType3 field descriptions	
allowedMeasBandwidth	30		
If absent, the value corresponding to the downlink bandwidth indicated by the dl-Bandwidth included in MasterInformationBlock applies. cellSelectionInfoCE		If E-UTRAN includes multiBandInfoList-v10j0, it includes the same number of entries, and listed in the same order, as in multiBandInfoList (i.e. without suffix). p-Max	
Parameters included in coverage enhancement S criteria. They may be used by the UE to select/reselect a cell in which it works in CE mode on the concerned non serving frequency. If absent, the UE acquires the information from the target cell on the concerned frequency. cellReselectionInfoCommon	35	Value applicable for the intra-frequency neighbouring E-UTRA cells. If absent the UE applies the maximum power according to the UE capability. redistrOnPagingOnly	
Cell re-selection information common for cells. cellReselectionServingFreqInfo	40	If this field is present and the UE is redistribution capable, the UE shall only wait for the paging message to trigger E-UTRAN inter-frequency redistribution procedure as specified in 5.2.4.10 of 36.304[4]. q-Hyst	
Information common for Cell re-selection to inter-frequency and inter-RAT cells. freqBandInfo	45	Parameter Q_{hyst} in 36.304 [4], Value in dB. Value dB1 corresponds to 1 dB, dB2 corresponds to 2 dB and so on. q-HystSF	
A list of additionalPmax and additionalSpectrumEmission values as defined in TS 36.101 [42, table 6.2.4-1] applicable for the intra-frequency neighbouring E-UTRA cells if the UE selects the frequency band from freqBandIndicator in SystemInformationBlockType1. intraFreqAsyncNeighCells	50	Parameter “Speed dependent ScalingFactor for Q_{hyst} ” in TS 36.304 [4]. The sf-Medium and sf-High concern the additional hysteresis to be applied, in Medium and High Mobility state respectively, to Q_{hyst} as defined in TS 36.304 [4]. In dB. Value dB-6 corresponds to -6 dB, dB-4 corresponds to -4 dB and so on. q-QualMin	
Indicates whether the intra-frequency neighbor cells are unsynchronized with the PCell. If present, the UE shall perform intra-frequency discovery signals measurement according to the intraFreqDMTC. If intraFreqAsyncNeighCells is set to true, and intraFreqDMTC is not present, the UE performs intra-frequency discovery signals measurement on neighbour cells assuming any possible discovery signals timing, intraFreqcellReselectionInfo	55	Parameter “ $Q_{qualmin}$ ” in TS 36.304 [4], applicable for intra-frequency neighbour cells. If the field is not present, the UE applies the (default) value of negative infinity for $Q_{qualmin}$. NOTE 1. q-QualMinRSRQ-OnAllSymbols	
Cell re-selection information common for intra-frequency cells. intraFreqDMTC	60	If this field is present and supported by the UE, the UE shall, when performing RSRQ measurements, perform RSRQ measurement on all OFDM symbols in accordance with TS 36.214 [48]. NOTE 1. q-QualMinWB	
Indicates the discovery signals measurement timing configuration (DMTC) for intra-frequency neighbour cells. multiBandInfoList-v10j0	65	If this field is present and supported by the UE, the UE shall, when performing RSRQ measurements, use a wider bandwidth in accordance with TS 36.133 [16]. NOTE 1. q-RxLevMin	
A list of additionalPmax and additionalSpectrumEmission values as defined in TS 36.101 [42, table 6.2.4-1] applicable for the intra-frequency neighbouring E-UTRA cells if the UE selects the frequency bands in multiBandInfoList (i.e. without suffix) or multiBandInfoList-v9e0.		Parameter “ $Q_{rxlevmin}$ ” in TS 36.304 [4], applicable for intra-frequency neighbour cells.	

SystemInformationBlockType3 field descriptions	
redistributionFactorCell	5
If redistributionFactorCell is present, redistributionFactorServing is only applicable for the serving cell otherwise it is applicable for serving frequency	
redistributionFactorServing	10
Parameter redistributionFactorServing in TS 36.304 [4].	
s-IntraSearch	15
Parameter “ $S_{IntraSearchP}$ ” in TS 36.304 [4]. If the field s-IntraSearchP is present, the UE applies the value of s-IntraSearchP instead. Otherwise if neither s-IntraSearch nor s-IntraSearchP is present, the UE applies the (default) value of infinity for $S_{IntraSearchP}$.	
s-IntraSearchP	20
Parameter “ $S_{IntraSearchP}$ ” in TS 36.304 [4]. See descriptions under s-IntraSearch.	
s-IntraSearchQ	25
Parameter “ $S_{IntraSearchQ}$ ” in TS 36.304 [4]. If the field is not present, the UE applies the (default) value of 0 dB for $S_{IntraSearchQ}$.	
s-NonIntraSearch	30
Parameter “ $S_{nonIntraSearchP}$ ” in TS 36.304 [4]. If the field s-NonIntraSearchP is present, the UE applies the value of s-NonIntraSearchP instead. Otherwise if neither s-NonIntraSearch nor s-NonIntraSearchP is present, the UE applies the (default) value of infinity for $S_{nonIntraSearchP}$.	
s-NonIntraSearchP	
Parameter “ $S_{nonIntraSearchP}$ ” in TS 36.304 [4]. See descriptions under s-NonIntraSearch.	

SystemInformationBlockType3 field descriptions	
s-NonIntraSearchQ	10
Parameter “ $S_{nonIntraSearchQ}$ ” in TS 36.304 [4]. If the field is not present, the UE applies the (default) value of 0 dB for $S_{nonIntraSearchQ}$.	
speedStateReselectionPars	15
Speed dependent reselection parameters, see TS 36.304 [4]. If this field is absent, i.e, mobilityStateParameters is also not present, UE behaviour is specified in TS 36.304 [4].	
t360	20
Parameter “T360” in TS 36.304 [4].	
threshServingLow	25
Parameter “ $Thresh_{Serving, LowP}$ ” in TS 36.304 [4].	
threshServingLowQ	30
Parameter “ $Thresh_{Serving, LowQ}$ ” in TS 36.304 [4].	
t-ReselectionEUTRA	
Parameter “ $Treselection_{EUTRA}$ ” in TS 36.304 [4].	
t-ReselectionEUTRA-SF	
Parameter “Speed dependent ScalingFactor for $Treselection_{EUTRA}$ ” in TS 36.304 [4]. If the field is not present, the UE behaviour is specified in TS 36.304 [4].	

The IE SystemInformationBlockType5 contains information relevant only for inter-frequency cell re-selection, i.e. information about other Evolved Universal Terrestrial Radio Access (E-UTRA) frequencies and inter-frequency neighboring cells relevant for cell re-selection. The IE includes cell re-selection parameters common for a frequency as well as cell specific re-selection parameters.

SystemInformationBlockType5 information element			
-- ASN1START			
SystemInformationBlockType5 ::=	SEQUENCE {		
interFreqCarrierFreqList	InterFreqCarrierFreqList,		
lateNonCriticalExtension	OCTET STRING (CONTAINING		
SystemInformationBlockType5-v8h0-IEs)	OPTIONAL,		
[[interFreqCarrierFreqList-v1250	InterFreqCarrierFreqList-v1250	OPTIONAL,	-
- Need OR			
interFreqCarrierFreqListExt-r12	InterFreqCarrierFreqListExt-r12	OPTIONAL	-
- Need OR			
]],			
[[interFreqCarrierFreqListExt-v1280	InterFreqCarrierFreqListExt-v1280	OPTIONAL	
-- Need OR			
]],			
[[interFreqCarrierFreqList-v1310	InterFreqCarrierFreqList-v1310	OPTIONAL,	
-- Need OR			
interFreqCarrierFreqListExt-v1310	InterFreqCarrierFreqListExt-v1310	OPTIONAL	
-- Need OR			
]]			
}			
SystemInformationBlockType5-v8h0-IEs ::=	SEQUENCE {		
interFreqCarrierFreqList-v8h0	SEQUENCE (SIZE (1..maxFreq)) OF		
InterFreqCarrierFreqInfo-v8h0	OPTIONAL, -- Need OP		
nonCriticalExtension	SystemInformationBlockType5-v9e0-IEs		
OPTIONAL			
}			
SystemInformationBlockType5-v9e0-IEs ::=	SEQUENCE {		
interFreqCarrierFreqList-v9e0	SEQUENCE (SIZE (1..maxFreq)) OF		
InterFreqCarrierFreqInfo-v9e0	OPTIONAL, -- Need OR		
nonCriticalExtension	SystemInformationBlockType5-v10j0-IEs	OPTIONAL	
}			
SystemInformationBlockType5-v10j0-IEs ::=	SEQUENCE {		
interFreqCarrierFreqList-v10j0	SEQUENCE (SIZE (1..maxFreq)) OF		
InterFreqCarrierFreqInfo-v10j0	OPTIONAL, -- Need OR		
nonCriticalExtension	SEQUENCE { }	OPTIONAL	
}			

-continued

SystemInformationBlockType5 information element			
InterFreqCarrierFreqList ::=	SEQUENCE (SIZE (1..maxFreq)) OF		
InterFreqCarrierFreqInfo			
InterFreqCarrierFreqList-v1250 ::=	SEQUENCE (SIZE (1.. maxFreq)) OF		
InterFreqCarrierFreqInfo-v1250			
InterFreqCarrierFreqListExt-r12 ::=	SEQUENCE (SIZE (1.. maxFreq)) OF		
InterFreqCarrierFreqInfo-r12			
InterFreqCarrierFreqListExt-v1280 ::=	SEQUENCE (SIZE (1.. maxFreq)) OF		
InterFreqCarrierFreqInfo-v10j0			
InterFreqCarrierFreqList-v1310 ::=	SEQUENCE (SIZE (1.. maxFreq)) OF		
InterFreqCarrierFreqInfo-v1310			
InterFreqCarrierFreqListExt-v1310 ::=	SEQUENCE (SIZE (1.. maxFreq)) OF		
InterFreqCarrierFreqInfo-v1310			
InterFreqCarrierFreqInfo ::=	SEQUENCE {		
dl-CarrierFreq	ARFCN-ValueEUTRA,		
q-RxLevMin	Q-RxLevMin,		
p-Max	P-Max	OPTIONAL,	-
- Need OP			
t-ReselectionEUTRA	T-Reselection,		
t-ReselectionEUTRA-SF	SpeedStateScaleFactors	OPTIONAL,	-
- Need OP			
threshX-High	ReselectionThreshold,		
threshX-Low	ReselectionThreshold,		
allowedMeasBandwidth	AllowedMeasBandwidth,		
presenceAntennaPort1	PresenceAntennaPort1,		
cellReselectionPriority	CellReselectionPriority	OPTIONAL,	-
- Need OP			
neighCellConfig	NeighCellConfig,		
q-OffsetFreq	Q-OffsetRange	DEFAULT dB0,	
interFreqNeighCellList	InterFreqNeighCellList	OPTIONAL,	-
- Need OR			
interFreqBlackCellList	InterFreqBlackCellList	OPTIONAL,	-
- Need OR			
...			
[[q-QualMin-r9	Q-QualMin-r9	OPTIONAL,	-
- Need OP			
threshX-Q-r9	SEQUENCE {		
threshX-HighQ-r9	ReselectionThresholdQ-r9,		
threshX-LowQ-r9	ReselectionThresholdQ-r9		
}		OPTIONAL	-
- Cond RSRQ			
]],			
[[q-QualMinWB-r11	Q-QualMin-r9	OPTIONAL	--
Cond WB-RSRQ			
]]			
// asyncNeighCells-MF	BOOLEAN	OPTIONAL	-
- Need OP			
neighborCellDMTC-MF	MeasDS-Config-MF	OPTIONAL	-
- Need OP			
//			
}			
InterFreqCarrierFreqInfo-v8h0 ::=	SEQUENCE {		
multiBandInfoList	MultiBandInfoList	OPTIONAL	--
Need OR			
}			
InterFreqCarrierFreqInfo-v9e0 ::=	SEQUENCE {		
dl-CarrierFreq-v9e0	ARFCN-ValueEUTRA-v9e0	OPTIONAL,	-- Cond dl-
FreqMax			
multiBandInfoList-v9e0	MultiBandInfoList-v9e0	OPTIONAL,	-- Need OR
}			
InterFreqCarrierFreqInfo-v10j0 ::=	SEQUENCE {		
freqBandInfo-r10	NS-PmaxList-r10	OPTIONAL,	-- Need
OR			
multiBandInfoList-v10j0	MultiBandInfoList-v10j0	OPTIONAL	-- Need
OR			
}			
InterFreqCarrierFreqInfo-v1250 ::=	SEQUENCE {		
reducedMeasPerformance-r12	ENUMERATED {true}	OPTIONAL,	-- Need OP
q-QualMinRSRQ-OnAllSymbols-r12	Q-QualMin-r9	OPTIONAL	-- Cond
RSRQ2			
}			
InterFreqCarrierFreqInfo-r12 ::=	SEQUENCE {		
dl-CarrierFreq-r12	ARFCN-ValueEUTRA-r9,		
q-RxLevMin-r12	Q-RxLevMin,		
p-Max-r12	P-Max	OPTIONAL,	-
- Need OP			
t-ReselectionEUTRA-r12	T-Reselection,		
t-ReselectionEUTRA-SF-r12	SpeedStateScaleFactors	OPTIONAL,	-

-continued

SystemInformationBlockType5 information element			
- Need OP	threshX-High-r12	ReselectionThreshold,	
	threshX-Low-r12	ReselectionThreshold,	
	allowedMeasBandwidth-r12	AllowedMeasBandwidth,	
	presenceAntennaPort1-r12	PresenceAntennaPort1,	
	cellReselectionPriority-r12	CellReselectionPriority	OPTIONAL, -
- Need OP	neighCellConfig-r12	NeighCellConfig,	
	q-OffsetFreq-r12	Q-OffsetRange	DEFAULT dB0,
	interFreqNeighCellList-r12	InterFreqNeighCellList	OPTIONAL, -
- Need OR	interFreqBlackCellList-r12	InterFreqBlackCellList	OPTIONAL, -
- Need OR	q-QualMin-r12	Q-QualMin-r9	OPTIONAL, -
- Need OP	threshX-Q-r12	SEQUENCE {	
	threshX-HighQ-r12	ReselectionThresholdQ-r9,	
	threshX-LowQ-r12	ReselectionThresholdQ-r9	
	}		OPTIONAL, --
Cond RSRQ	q-QualMinWB-r12	Q-QualMin-r9	OPTIONAL, --
Cond WB-RSRQ	multiBandInfoList-r12	MultiBandInfoList-r11	OPTIONAL, --
Need OR	reducedMeasPerformance-r12	ENUMERATED {true}	OPTIONAL, --
Need OP	q-QualMinRSRQ-OnAllSymbols-r12	Q-QualMin-r9	OPTIONAL, --
Cond RSRQ2			
...			
}			
InterFreqCarrierFreqInfo-v1310 ::=	SEQUENCE {		
cellReselectionSubPriority-r13	CellReselectionSubPriority-r13		OPTIONAL,
-- Need OP			
redistributionInterFreqInfo-r13	RedistributionInterFreqInfo-r13		OPTIONAL, --
Need OP	cellSelectionInfoCE-r13	CellSelectionInfoCE-r13	OPTIONAL, --
Need OP	t-ReselectionEUTRA-CE-r13	T-ReSelectionEUTRA-CE-r13	OPTIONAL --
Need OP			
}			
InterFreqNeighCellList ::=	SEQUENCE (SIZE (1..maxCellInter)) OF		
InterFreqNeighCellInfo			
InterFreqNeighCellInfo ::=	SEQUENCE {		
physCellId	PhysCellId,		
q-OffsetCell	Q-OffsetRange		
}			
InterFreqBlackCellList ::=	SEQUENCE (SIZE (1..maxCellBlack)) OF PhysCellIdRange		
RedistributionInterFreqInfo-r13 ::=	SEQUENCE {		
redistributionFactorFreq-r13	RedistributionFactor-r13		OPTIONAL, --
Need OP			
redistributionNeighCellList-r13	RedistributionNeighCellList-r13		OPTIONAL
--Need OP			
}			
RedistributionNeighCellList-r13 ::=	SEQUENCE (SIZE (1..maxCellInter)) OF		
	RedistributionNeighCell-r13		
RedistributionNeighCell-r13 ::=	SEQUENCE {		
physCellId-r13	PhysCellId,		
redistributionFactorCell-r13	RedistributionFactor-r13		
}			
RedistributionFactor-r13 ::=	INTEGER(1..10)		
-- ASN1STOP			

55

SystemInformationBlockType5 field descriptions	
asyncNeighCells	
Indicates whether the neighbor cells on the carrier frequency indicated by dl-CarrierFreq are unsynchronized with the PCell. If present, the UE performs discovery signals measurement on the carrier frequency indicated by dl-CarrierFreq according to the measDS-Config. If set to true, and measDS-Config is not present, the UE performs discovery signals measurement on the carrier frequency indicated by dl-CarrierFreq assuming any possible discovery signals timing,	

-continued

SystemInformationBlockType5 field descriptions	
freqBandInfo	
60	A list of additionalPmax and additionalSpectrumEmission values as defined in TS 36.101 [42, table 6.2.4-1] for the frequency band represented by dl-CarrierFreq for which cell reselection parameters are common.
interFreqBlackCellList	
65	List of blacklisted inter-frequency neighbouring cells.

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-continued

SystemInformationBlockType5 field descriptions	
interFreqCarrierFreqList	
List of neighbouring inter-frequencies. E-UTRAN does not configure more than one entry for the same physical frequency regardless of the E-ARFCN used to indicate this. If E-UTRAN includes interFreqCarrierFreqList-v8h0, interFreqCarrierFreqList-v9e0, InterFreqCarrierFreqList-v1250 and/or InterFreqCarrierFreqList-v1310, it includes the same number of entries, and listed in the same order, as in interFreqCarrierFreqList (i.e. without suffix). See Annex D for more descriptions.	
interFreqCarrierFreqListExt	
List of additional neighbouring inter-frequencies, i.e. extending the size of the inter-frequency carrier list using the general principles specified in 5.1.2. E-UTRAN does not configure more than one entry for the same physical frequency regardless of the E-ARFCN used to indicate this. EUTRAN may include interFreqCarrierFreqListExt even if interFreqCarrierFreqList (i.e without suffix) does not include maxFreq entries. If E-UTRAN includes InterFreqCarrierFreqListExt-v1310 it includes the same number of entries, and listed in the same order, as in interFreqCarrierFreqListExt-r12.	
interFreqNeighCellList	
List of inter-frequency neighbouring cells with specific cell re-selection parameters.	
multiBandInfoList	
Indicates the list of frequency bands in addition to the band represented by dl-CarrierFreq for which cell reselection parameters are common. E-UTRAN indicates at most maxMultiBands frequency bands (i.e. the total number of entries across both multiBandInfoList and multiBandInfoList-v9e0 is below this limit).	
multiBandInfoList-v10j0	
A list of additionalPmax and additionalSpectrumEmission values as defined in TS 36.101 [42, table 6.2.4-1] for the frequency bands in multiBandInfoList (i.e. without suffix) and multiBandInfoList-v9e0. If E-UTRAN includes multiBandInfoList-v10j0, it includes the same number of entries, and listed in the same order, as in multiBandInfoList (i.e. without suffix).	
neighCellDMTC-Config	
Parameters applicable to discovery signals measurement on the carrier frequency indicated by dl-CarrierFreq.	
p-Max	
Value applicable for the neighbouring E-UTRA cells on this carrier frequency. If absent the UE applies the maximum power according to the UE capability.	
q-OffsetCell	
Parameter “Qoffset _{s, n} ” in TS 36.304 [4].	
q-OffsetFreq	
Parameter “Qoffset _{frequency} ” in TS 36.304 [4].	
q-QualMin	
Parameter “Q _{qualmin} ” in TS 36.304 [4]. If the field is not present, the UE applies the (default) value of negative infinity for Q _{qualmin} . NOTE 1.	
q-QualMinRSRQ-OnAllSymbols	
If this field is present and supported by the UE, the UE shall, when performing RSRQ measurements, perform RSRQ measurement on all OFDM symbols in accordance with TS 36.214 [48]. NOTE 1.	
q-QualMinWB	
If this field is present and supported by the UE, the UE shall, when performing RSRQ measurements, use a wider bandwidth in accordance with TS 36.133 [16]. NOTE 1.	
redistributionFactorFreq	
Parameter redistributionFactorFreq in TS 36.304 [4].	

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-continued

SystemInformationBlockType5 field descriptions	
redistributionFactorCell	
Parameter redistributionFactorCell in TS 36.304 [4].	
reducedMeasPerformance	
Value TRUE indicates that the neighbouring inter-frequency is configured for reduced measurement performance, see TS 36.133 [16].	
threshX-High	
Parameter “Thresh _{X, HighP} ” in TS 36.304 [4].	
threshX-HighQ	
Parameter “Thresh _{X, HighQ} ” in TS 36.304 [4].	
threshX-Low	
Parameter “Thresh _{X, LowP} ” in TS 36.304 [4].	
threshX-LowQ	
Parameter “Thresh _{X, LowQ} ” in TS 36.304 [4].	
t-ReselectionEUTRA	
Parameter “Tresselection _{EUTRA} ” in TS 36.304 [4].	
t-ReselectionEUTRA-SF	
Parameter “Speed dependent ScalingFactor for Tresselection _{EUTRA} ” in TS 36.304 [4]. If the field is not present, the UE behaviour is specified in TS 36.304 [4].	

FIG. 11 illustrates the operation of the radio access node **14** and the wireless device **12** according to some embodiments of the present disclosure in which a DMTC is provided to the wireless device **12** for a carrier frequency together with a respective async indication within a measurement object used to configure the wireless device **12** to perform measurements on the carrier frequency. As illustrated, the radio access node **14** sends a measurement object to the wireless device **12** where the measurement object includes: (a) an async indication for a respective carrier frequency and (b) a DMTC for the carrier frequency to be used if the async indication for the downlink carrier frequency is set to a value that indicates that one or more asynchronous cells are operating on the downlink carrier frequency (i.e., indicates that there are asynchronous cell(s) on the downlink carrier frequency) (step **300**). The wireless device **12** utilizes the DMTC for the carrier frequency (step **302**). The wireless device **12** may use the DMTC to perform measurements such as RRM measurements on the asynchronous cells on the carrier frequency indicated in the measurement object.

Below, an example of a measurement object, namely MeasObjectEUTRA, including the async indication and DMTC configuration for a specified carrier frequency are provided below. Note that, as discussed above, the measurement object may be further modified to include a separate DMTC configuration for synchronous cells on the specified carrier frequency and, in some embodiments, a sync indication that, if set, indicates that there are synchronous cells on the specified carrier frequency (and thus that the wireless device **12** should use the DMTC provided for synchronous cells when performing measurements on the specified carrier frequency). In the example below, portions related to DMTC and async indication are bolded and italicized.

The IE MeasObjectEUTRA specifies information applicable for intra-frequency or inter-frequency E-UTRA cells.

MeasObjectEUTRA information element

```

-- ASN1START
MeasObjectEUTRA ::=
    carrierFreq
    allowedMeasBandwidth
    presenceAntennaPort1
    neighCellConfig
    offsetFreq
    -- Cell list
    cellsToRemoveList
Need ON
    cellsToAddModList
Need ON
    -- Black list
    blackCellsToRemoveList
Need ON
    blackCellsToAddModList
Need ON
    cellForWhichToReportCGI
Need ON
    . . . ,
    [[measCycleSCell-r10
ON
    measSubframePatternConfigNeigh-r10
    ]],
    [[widebandRSRQ-Meas-r11
    ]],
    [[ altTTT-CellsToRemoveList-r12
Need ON
    altTTT-CellsToAddModList-r12
- Need ON
    t312-r12
        release
        setup
    }
ON
    reducedMeasPerformance-r12
Need ON
    measDS-Config-r12
Need ON
    ]],
    [[
        whiteCellsToRemoveList-r13
Need ON
        whiteCellsToAddModList-r13
Need ON
        rmtc-Config-r13
        carrierFreq-r13
- Need ON
    ]],
    //
    asyncNeighCells-MF
Need ON
    measDS-Config-MF
Need ON
    //
}
MeasObjectEUTRA-v9e0 ::=
    carrierFreq-v9e0
}
CellsToAddModList ::=
CellsToAddMod ::= SEQUENCE {
    cellIndex
    physCellId
    cellIndividualOffset
}
BlackCellsToAddModList ::=
BlackCellsToAddMod
BlackCellsToAddMod ::= SEQUENCE {
    cellIndex
    physCellIdRange
}
MeasCycleSCell-r10 ::=
    ENUMERATED {sf160, sf256, sf320, sf512,
                sf640, sf1024, sf1280, spare1}
MeasSubframePatternConfigNeigh-r10 ::=
    CHOICE {
        release
        setup
        measSubframePatternNeigh-r10

```

```

SEQUENCE {
    ARFCN-ValueEUTRA,
    AllowedMeasBandwidth,
    PresenceAntennaPort1,
    NeighCellConfig,
    Q-OffsetRange
    DEFAULT dB0,
    CellIndexList
    OPTIONAL, --
    CellsToAddModList
    OPTIONAL, --
    CellIndexList
    OPTIONAL, --
    BlackCellsToAddModList
    OPTIONAL, --
    PhysCellId
    OPTIONAL, --
    MeasCycleSCell-r10
    OPTIONAL, -- Need
    MeasSubframePatternConfigNeigh-r10
    OPTIONAL
    BOOLEAN
    OPTIONAL -- Cond WB-RSRQ
    CellIndexList
    OPTIONAL, --
    AltTTT-CellsToAddModList-r12
    OPTIONAL, -
    CHOICE {
        NULL,
        ENUMERATED {ms0, ms50, ms100, ms200,
                    ms300, ms400, ms500, ms1000}
    }
    OPTIONAL, -- Need
    BOOLEAN
    OPTIONAL, --
    MeasDS-Config-r12
    OPTIONAL --
    CellIndexList
    OPTIONAL, --
    WhiteCellsToAddModList-r13
    OPTIONAL, --
    RMTC-Config-r13
    OPTIONAL, -- Need ON
    ARFCN-ValueEUTRA-v9e0
    OPTIONAL -
    BOOLEAN
    OPTIONAL, --
    MeasDS-Config-MF
    OPTIONAL, --

```

```

SEQUENCE {
    ARFCN-ValueEUTRA-v9e0
}
SEQUENCE (SIZE (1..maxCellMeas)) OF CellsToAddMod
    INTEGER (1..maxCellMeas),
    PhysCellId,
    Q-OffsetRange
}
SEQUENCE (SIZE (1..maxCellMeas)) OF
    INTEGER (1..maxCellMeas),
    PhysCellIdRange
}
ENUMERATED {sf160, sf256, sf320, sf512,
            sf640, sf1024, sf1280, spare1}
CHOICE {
    NULL,
    SEQUENCE {
        MeasSubframePattern-r10,

```



```

MeasObjectEUTRA information element
-----
measSubframeCellList-r10                               MeasSubframeCellList-r10  OPTIONAL  -
- Cond always
  }
}
MeasSubframeCellList-r10 ::= SEQUENCE (SIZE (1..maxCellMeas)) OF PhysCellIdRange
AltTTT-CellsToAddModList-r12 ::= SEQUENCE (SIZE (1..maxCellMeas)) OF AltTTT-
CellsToAddMod-r12
AltTTT-CellsToAddMod-r12 ::= SEQUENCE {
    cellIndex-r12                               INTEGER (1..maxCellMeas),
    physCellIdRange-r12                         PhysCellIdRange
}
WhiteCellsToAddModList-r13 ::= SEQUENCE (SIZE (1..maxCellMeas)) OF
WhiteCellsToAddMod-r13
WhiteCellsToAddMod-r13 ::= SEQUENCE {
    cellIndex-r13                               INTEGER (1..maxCellMeas),
    physCellIdRange-r13                         PhysCellIdRange
}
RMTC-Config-r13 ::= CHOICE {
    release                                     NULL,
    setup                                     SEQUENCE {
        rmtc-Period-r13                       ENUMERATED {ms40, ms80, ms160, ms320, ms640},
        rmtc-SubframeOffset-r13               INTEGER(0..639)                               OPTIONAL, -
    }
- Need ON
    measDuration-r13                           ENUMERATED {sym1, sym14, sym28, sym42, sym70},
    ...
}
}
-- ASN1STOP

```

MeasObjectEUTRA field descriptions	30	-continued
altTTT-CellsToAddModList		MeasObjectEUTRA field descriptions
List of cells to add/modify in the cell list for which the alternative time to trigger specified by alternativeTimeToTrigger in reportConfigEUTRA, if configured, applies.		cellsToRemoveList
altTTT-CellsToRemoveList		
List of cells to remove from the list of cells for alternative time to trigger.		
asyncNeighCells		
Indicates whether the neighbor cells on the carrier frequency indicated by carrierFreq are unsynchronized with the PCell. If present, the UE shall perform discovery signals measurement on the carrier frequency indicated by carrierFreq according to the measDS-Config. If set to true, and measDS-Config is not present, the UE shall perform discovery signals measurement on the carrier frequency indicated by carrierFreq assuming any possible discovery signals timing,		
blackCellsToAddModList		
List of cells to add/modify in the black list of cells.		
blackCellsToRemoveList		
List of cells to remove from the black list of cells.		
carrierFreq		
Identifies E-UTRA carrier frequency for which this configuration is valid. E-UTRAN does not configure more than one measurement object for the same physical frequency regardless of the E-ARFCN used to indicate this. CarrierFreq-r13 is included only when the extension list measObjectToAddModListExt-r13 is used. If carrierFreq-r13 is present, carrierFreq (i.e., without suffix) shall be set to value maxEARFCN.		
cellIndex		
Entry index in the cell list. An entry may concern a range of cells, in which case this value applies to the entire range.		
cellIndividualOffset		
Cell individual offset applicable to a specific cell. Value dB-24 corresponds to -24 dB, dB-22 corresponds to -22 dB and so on.		
cellsToAddModList		
List of cells to add/modify in the cell list.		
	35	List of cells to remove from the cell list.
		measCycleSCell
		The parameter is used only when an SCell is configured on the frequency indicated by the measObject and is in deactivated state, see TS 36.133 [16, 8.3.3]. E-UTRAN configures the parameter whenever an SCell is configured on the frequency indicated by the measObject, but the field may also be signalled when an SCell is not configured. Value sf160 corresponds to 160 sub-frames, sf256 corresponds to 256 sub-frames and so on.
	40	measDS-Config
		Parameters applicable to discovery signals measurement on the carrier frequency indicated by carrierFreq.
	45	measDuration
		Number of consecutive symbols for which the Physical Layer reports samples of RSSI, see TS 36.214 [48]. Value sym1 corresponds to one symbol, sym14 corresponds to 14 symbols, and so on.
	50	measSubframeCellList
		List of cells for which measSubframePatternNeigh is applied.
		measSubframePatternNeigh
		Time domain measurement resource restriction pattern applicable to neighbour cell RSRP and RSRQ measurements on the carrier frequency indicated by carrierFreq. For cells in measSubframeCellList the UE shall assume that the subframes indicated by measSubframePatternNeigh are non-MBSFN subframes, and have the same special subframe configuration as PCell.
	55	offsetFreq
		Offset value applicable to the carrier frequency. Value dB-24 corresponds to -24 dB, dB-22 corresponds to -22 dB and so on.
	60	physCellId
		Physical cell identity of a cell in the cell list.
		physCellIdRange
	65	Physical cell identity or a range of physical cell identities.

MeasObjectEUTRA field descriptions
reducedMeasPerformance
If set to TRUE, the EUTRA carrier frequency is configured for reduced measurement performance, otherwise it is configured for normal measurement performance, see TS 36.133 [16].
rmtc-Config
Parameters applicable to RSSI and channel occupancy measurement on the carrier frequency indicated by carrierFreq.
rmtc-Period
Indicates the RSSI measurement timing configuration (RMTTC) periodicity for this frequency. Value ms40 corresponds to 40 ms periodicity, ms80 corresponds to 80 ms periodicity and so on, see TS 36.214 [48].
rmtc-SubframeOffset
Indicates the RSSI measurement timing configuration (RMTTC) subframe offset for this frequency. The value of rmtc-SubframeOffset should be smaller than the value of rmtc-Period, see TS 36.214 [48]. For inter-frequency measurements, this field is optional present and if it is not configured, the UE chooses a

MeasObjectEUTRA field descriptions
random value as rmtc-SubframeOffset for measDuration which shall be selected to be between 0 and the configured rmtc-Period with equal probability.
t312
The value of timer T312. Value ms 0 represents 0 ms, ms 50 represents 50 ms and so on.
widebandRSRQ-Meas
If this field is set to TRUE, the UE shall, when performing RSRQ measurements, use a wider bandwidth in accordance with TS 36.133 [16].
whiteCellsToAddModList
List of cells to add/modify in the white list of cells.
whiteCellsToRemoveList
List of cells to remove from the white list of cells.

Below is an example of MeasDS-Config which is used in the examples above. The IE MeasDS-Config specifies information applicable for discovery signals measurement.

MeasDS-Config information elements			
<hr/>			
-- ASN1START			
MeasDS-Config-r12 ::=	CHOICE {		
release	NULL,		
setup	SEQUENCE {		
dmtdc-PeriodOffset-r12	CHOICE {		
ms40-r12	INTEGER(0..39),		
ms80-r12	INTEGER(0..79),		
ms160-r12	INTEGER(0..159),		
...			
}			
ds-OccasionDuration-r12	CHOICE {		
durationFDD-r12	INTEGER(1..maxDS-Duration-r12),		
durationTDD-r12	INTEGER(2..maxDS-Duration-r12)		
}			
measCSI-RS-ToRemoveList-r12	MeasCSI-RS-ToRemoveList-r12 OPTIONAL,		-- Need ON
measCSI-RS-ToAddModList-r12	MeasCSI-RS-ToAddModList-r12 OPTIONAL,		-- Need ON
...			
}			
}			
MeasDS-Config-MF ::=	CHOICE {		
release	NULL,		
setup	SEQUENCE {		
dmtdc-Period-MF	ENUMERATED {ms40, ms80, ms160},		
dmtdc-Offet-MF	INTEGER(0..159),		
dmtdc-Duration-MF	INTEGER(1..10),		
measCSI-RS-ToRemoveList-MF	MeasCSI-RS-ToRemoveList-r12 OPTIONAL,		-- Need ON
measCSI-RS-ToAddModList-MF	MeasCSI-RS-ToAddModList-r12 OPTIONAL,		-- Need ON
...			
}			
}			
MeasCSI-RS-ToRemoveList-r12 ::=	SEQUENCE (SIZE (1..maxCSI-RS-Meas-r12)) OF MeasCSI-RS-Id-		
r12			
MeasCSI-RS-ToAddModList-r12 ::=	SEQUENCE (SIZE (1..maxCSI-RS-Meas-r12)) OF MeasCSI-RS-		
Config-r12			
MeasCSI-RS-Id-r12 ::=	INTEGER (1..maxCSI-RS-Meas-r12)		
MeasCSI-RS-Config-r12 ::=	SEQUENCE {		
measCSI-RS-Id-r12	MeasCSI-RS-Id-r12,		
physCellId-r12	INTEGER (0..503),		
scramblingIdentity-r12	INTEGER (0..503),		
resourceConfig-r12	INTEGER (0..31),		
subframeOffset-r12	INTEGER (0..4),		
csi-RS-IndividualOffset-r12	Q-OffsetRange,		
...			
}			
-- ASN1STOP			

MeasDS-Config field descriptions
csi-RS-IndividualOffset
CSI-RS individual offset applicable to a specific CSI-RS resource. Value dB-24 corresponds to -24 dB, dB-22 corresponds to -22 dB and so on.
dmtc-Duration
Indicates the duration in number of subframes during which the UE shall expect discovery signals.
dmtc-Period
Indicates the discovery signals measurement timing configuration (DMTC) periodicity (dmtc-Periodicity). Value ms40 corresponds to 40 ms, ms80 corresponds to 80 ms and so on.
dmtc-Offset
Indicates the discovery signals measurement timing configuration (DMTC) offset (dmtc-Offset). The value of DMTC offset is in number of subframe(s).
dmtc-PeriodOffset
Indicates the discovery signals measurement timing configuration (DMTC) periodicity (dmtc-Periodicity) and offset (dmtc-Offset) for this frequency. For DMTC periodicity, value ms40 corresponds to 40 ms, ms80 corresponds to 80 ms and so on. The value of DMTC offset is in number of subframe(s). The duration of a DMTC occasion is 6 ms.
ds-OccasionDuration
Indicates the duration of discovery signal occasion for this frequency. Discovery signal occasion duration is common for all cells transmitting discovery signals on one frequency. The UE shall ignore the field ds-OccasionDuration for a carrier frequency with a configured LAA SCell and apply a value 1 instead.
measCSI-RS-ToAddModList
List of CSI-RS resources to add/modify in the CSI-RS resource list for discovery signals measurement.
measCSI-RS-ToRemoveList
List of CSI-RS resources to remove from the CSI-RS resource list for discovery signals measurement.
physCellId
Indicates the physical cell identity where UE may assume that the CSI-RS and the PSS/SSS/CRS corresponding to the indicated physical cell identity are quasi co-located with respect to average delay and doppler shift.
resourceConfig
Parameter: CSI reference signal configuration, see TS 36.211 [21, table 6.10.5.2-1 and 6.10.5.2-2]. For a carrier frequency with a configured LAA SCell, E-UTRAN does not configure the values {0, 4, 5, 9, 10, 11, 18, 19}.
scramblingIdentity
Parameter: Pseudo-random sequence generator parameter, n_{ID} , see TS 36.213 [23, 7.2.5].
subframeOffset
Indicates the subframe offset between SSS of the cell indicated by physCellId and the CSI-RS resource in a discovery signal occasion. The field subframeOffset is set to values 0 for a carrier frequency with a configured LAA SCell.

In some embodiments, the wireless device **12** sets up the DMTC in accordance with the received dmtc-PeriodOffset or dmtc-Period-MF and dmtc-Offset-MF, respectively, i.e., the first subframe of each DMTC occasion occurs at a System Frame Number (SFN) and subframe of the PCell meeting the following condition:

$$\text{SFN mod } T = \text{FLOOR}(\text{dmtc-Offset}/10);$$

$$\text{subframe} = \text{dmtc-Offset mod } 10;$$

$$\text{with } T = \text{dmtc-Periodicity}/10;$$

On the concerned frequency, the wireless device **12** considers DRS transmission in subframes outside the DMTC occasion.

In certain embodiments according to option **3**, as illustrated in FIG. **12**, a method in an eNB (e.g., a method in a radio access node **14**) comprises determining whether to configure a SCell (step **400**); in response to determining to configure the SCell, determining whether the async indication is provided for the corresponding frequency (step **402**); and in response to determining that the async indication is provided for the corresponding frequency, sending the SCell's DMTC configuration in the SCell addition (step **404**). The SCell addition may be provided via an RRCConnectionReconfiguration message, as described above.

Thus, in some embodiments, a method in a radio access node **14** for informing a wireless communication device **12** about the discovery signal timing, during which a wireless communication device is required to search for SCell discovery signals apart from the timing received via system information for other network nodes, comprises: determining a SCell for configuration; determining whether the neighbor cells on the SCell frequency are asynchronous; and indicating to the device the exact DMTC for the SCell via dedicated signaling.

In certain embodiments according to option **3**, as illustrated in FIG. **13**, a method in a UE (e.g., the wireless device **12**) comprises determining whether the SCell addition includes DMTC configuration for the SCell (step **500**); in response to determining that the SCell addition includes DMTC configuration for the SCell, (a) prioritizing measurements according to the DMTC configuration provided via dedicated signaling for SCell measurements (step **502**); and (b) if the async bit is set to a value that indicates that one or more asynchronous cells are operating on the frequency (step **504**; YES), performing best effort measurements on the neighbor cells on the frequency where the SCell has been added (step **506**). The method may use inter-frequency DMTC provided via system information to minimize its battery consumption during RRM measurements. The inter-frequency DMTC may be provided on SIB5, for example. Note that the UE may prioritize measurements by, for example, performing those measurements more frequently. Another example could be that, if the UE can only process a limited number of cells, the UE prioritizes the cells found in the prioritized DMTC. Further note that performing best effort measurements means that there are no requirements for how quickly the UE needs to find a report these cells and that it can choose not to search to, e.g., save battery.

Thus, in some embodiments, a method in a wireless communication device **12** comprises: determining whether the DMTC configuration is present in the SCell addition; configuring and prioritizing the DMTC for discovery signal measurements for the SCell; performing measurements for the SCell; and attempting to detect the discovery signals from neighbor cells on the SCell frequency and performing measurements on neighbor cells on the SCell frequency when possible.

As illustrated in FIG. **14**, the method may further comprise, if the SCell configuration is removed (step **600**, YES), deleting (i.e., removing) the DMTC configuration for the SCell (step **602**) and performing discovery signal measurements according to the DMTC configuration in, e.g., SIB5 (step **604**).

Although wireless communication devices **12** may represent communication devices that include any suitable combination of hardware and/or software, these wireless communication devices may, in certain embodiments, rep-

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resent devices such as an example wireless communication device **12** illustrated in greater detail by FIGS. **15** and **16**. Similarly, although the illustrated radio access node **14** may represent network nodes that include any suitable combination of hardware and/or software, these nodes may, in particular embodiments, represent devices such as the example radio access node **14** illustrated in greater detail by FIGS. **17** through **19**.

Referring to FIG. **15**, the wireless communication device **12** comprises a processor **20** (e.g., a Central Processing Unit(s) (CPU(s)), Application Specific Integrated Circuit(s) (ASIC(s)), Field Programmable Gate Array(s) (FPGA(s)), and/or the like), a memory **22**, a transceiver **24**, and an antenna **26**. In certain embodiments, some or all of the functionality described as being provided by UEs, MTC or M2M devices, and/or any other types of wireless communication devices may be provided by the processor **20** executing instructions stored on a computer readable medium, such as the memory **22** shown in FIG. **15**. Alternative embodiments may include additional components beyond those shown in FIG. **15** that may be responsible for providing certain aspects of the wireless communication device's functionality, including any of the functionality described herein.

FIG. **16** illustrates the wireless communication device **12** according to some other embodiments of the present disclosure. As illustrated, the wireless communication device **12** includes one or more modules **28**, each of which is implemented in software. The module(s) **28** operate to perform the functions of the wireless communication device **12** (e.g., UE, M2M UE, MTC UE, or the like) described herein. For example, the module(s) **28** may include a receiving module operable to receive a DMTC configuration as described herein and a utilizing module operable to utilize the DMTC configuration as described herein.

Referring to FIG. **17**, a radio access node **14** comprises a node processor **32** (e.g., a CPU(s), ASIC(s), FPGA(s), and/or the like), a memory **34**, a network interface **36**, a transceiver **38**, and an antenna **40**. As illustrated, together, the processor **32**, the memory **34**, and the network interface **36** are referred to as a control system **30**. In certain embodiments, some or all of the functionality described as being provided by a base station, a node B, an eNB, and/or any other type of network node may be provided by the node processor **32** executing instructions stored on a computer readable medium, such as the memory **34** shown in FIG. **17**. Alternative embodiments of the radio access node **14** may comprise additional components to provide additional functionality, such as the functionality described herein and/or related supporting functionality.

FIG. **18** is a schematic block diagram that illustrates a virtualized embodiment of the radio access node **14** according to some embodiments of the present disclosure. This discussion is equally applicable to other types of network nodes. Further, other types of network nodes may have similar virtualized architectures.

As used herein, a "virtualized" radio access node **14** is an implementation of the radio access node **14** in which at least a portion of the functionality of the radio access node **14** is implemented as a virtual component(s) (e.g., via a virtual machine(s) executing on a physical processing node(s) in a network(s)). As illustrated, in this example, the radio access node **14** includes the control system **30** that includes the processor(s) **32** (e.g., CPUs, ASICs, FPGAs, and/or the like), the memory **34**, and the network interface **36**. The radio access node **14** also includes the transceiver **38** coupled to the antenna(s) **40**. The control system **30** is

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connected to the transceiver **38** via, for example, an optical cable or the like. Alternatively, the control system **30**, the transceiver **38**, and the antennas **40** may, e.g., be integrated into a single unit. The control system **30** is connected to one or more processing nodes **42** coupled to or included as part of a network(s) **44** via the network interface **36**. Each processing node **42** includes one or more processors **46** (e.g., CPUs, ASICs, FPGAs, and/or the like), memory **48**, and a network interface **50**.

In this example, functions **52** of the radio access node **14** (e.g., functions of the eNB or base station) described herein are implemented at the one or more processing nodes **42** or distributed across the control system **30** and the one or more processing nodes **42** in any desired manner. In some particular embodiments, some or all of the functions **52** of the radio access node **14** described herein are implemented as virtual components executed by one or more virtual machines implemented in a virtual environment(s) hosted by the processing node(s) **42**. As will be appreciated by one of ordinary skill in the art, additional signaling or communication between the processing node(s) **42** and the control system **30** is used in order to carry out at least some of the desired functions **52**. Notably, in some embodiments, the control system **30** may not be included, in which case the transceiver **38** communicates directly with the processing node(s) **42** via an appropriate network interface(s).

FIG. **19** illustrates the radio access node **14** according to some other embodiments of the present disclosure. As illustrated, the radio access node **14** includes one or more modules **54**, each of which is implemented in software. The module(s) **54** operate to perform the functions of the radio access node **14** (e.g., eNB or base station) described herein. For example, the module(s) **54** may include a sending module operable to transmit a DMTC configuration as described herein.

The following acronyms are used throughout this disclosure.

- μs Microsecond
- 3GPP Third Generation Partnership Project
- AP Access Point
- ASIC Application Specific Integrated Circuit
- CA Carrier Aggregation
- CC Component Carrier
- CCA Clear Channel Assessment
- CFI Control Format Indicator
- CIF Carrier Indicator Field
- CPU Central Processing Unit
- CRS Cell-Specific Reference Symbol
- CSI-RS Channel State Information Reference Signal
- CSMA/CA Carrier Sense Multiple Access with Collision Avoidance
- DCI Downlink Control Information
- DFT Discrete Fourier Transform
- DMTC Discovery Signal Measurement Timing Configuration
- DRS Discovery Reference Signal
- DwPTS Downlink Part of the Special Subframe
- eNB Enhanced or Evolved Node B
- ePDCCH Enhanced Physical Downlink Control Channel
- eSIB Enhanced System Information Block
- E-UTRA Evolved Universal Terrestrial Radio Access
- FDD Frequency Division Duplexing
- FDMA Frequency Division Multiple Access
- FPGA Field Programmable Gate Array
- GHz Gigahertz
- HARQ Hybrid Automatic Repeat Request
- ID Identity

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IE Information Element
 LA License Assisted
 LAA License Assisted Access
 LBT Listen-Before-Talk
 LTE Long Term Evolution
 LTE-U Long Term Evolution in the Unlicensed Band
 M2M Machine-to-Machine
 MAC Medium Access Control
 MHz Megahertz
 ms Millisecond
 MTC Machine Type Communication
 NAS Non-Access Stratum
 OFDM Orthogonal Frequency Division Multiplexing
 PCell Primary Cell
 PCFICH Physical Control Format Indicator Channel
 PCID Physical Cell Identity
 PDCCH Physical Downlink Control Channel
 PDSCH Physical Downlink Shared Channel
 PSS Primary Synchronization Signal
 PUCCH Physical Uplink Control Channel
 PUSCH Physical Uplink Shared Channel
 RAT Radio Access Technology
 Rel Release
 RRC Radio Resource Control
 RRM Radio Resource Management
 RSRP Reference Signal Received Power
 RSRQ Reference Signal Received Quality
 RSSI Received Signal Strength Indicator
 SCell Secondary Cell
 SC-FDMA Single Carrier Frequency Division Multiple
 Access
 SFN System Frame Number
 SIB System Information Block
 SIB-MF MulteFire System Information Block
 SSS Secondary Synchronization Signal
 TDD Time Division Duplexing
 TS Technical Specification
 UE User Equipment
 VCID Virtual Cell Identity
 WLAN Wireless Local Area Network

Those skilled in the art will recognize improvements and modifications to the embodiments of the present disclosure. All such improvements and modifications are considered within the scope of the concepts disclosed herein and the claims that follow.

What is claimed is:

1. A method of operation of a radio access node in a cellular communications network, comprising:

sending, to a wireless device, one or more Discovery Signal Measurement Timing Configurations, DMTCs, for a frequency on which one or more asynchronous cells can be operating, an asynchronous cell being a cell that is unsynchronized with a primary cell of the wireless device;

wherein sending the one or more DMTCs comprises transmitting system information or a measurement object comprising:

an indication of whether one or more asynchronous cells are operating on the frequency;

if the indication is set to a value that indicates that one or more asynchronous cells are operating on the frequency, a first DMTC for the frequency to be used by the wireless device for one or more asynchronous cells operating on the frequency; and

if the indication is set to a value that indicates that there are no asynchronous cells operating on the frequency, a second DMTC for the frequency to be used

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by the wireless device for one or more synchronous cells operating on the frequency.

2. The method of claim 1 wherein transmitting the system information or the measurement object comprises transmitting the system information comprising:

the indication of whether one or more asynchronous cells are operating on the frequency, wherein the one or more asynchronous cells are one or more intra-frequency asynchronous cells;

if the indication is set to a value that indicates that one or more asynchronous cells are operating on the frequency, the first DMTC for the frequency to be used by the wireless device for one or more intra-frequency asynchronous cells operating on the frequency; and

if the indication is set to a value that indicates that there are no asynchronous cells operating on the frequency, the second DMTC for the frequency to be used by the wireless device for one or more intra-frequency synchronous cells operating on the frequency.

3. The method of claim 2 wherein each of the first DMTC and the second DMTC comprises at least one of a DMTC periodicity, a DMTC offset, and a DMTC duration.

4. The method of claim 2 wherein the system information is a System Information Block type 3, SIB3, information element.

5. The method of claim 1 wherein transmitting the system information or the measurement object comprises transmitting the system information comprising:

the indication of whether one or more asynchronous cells are operating on the frequency, wherein the one or more asynchronous cells are one or more inter-frequency asynchronous cells;

if the indication is set to a value that indicates that one or more asynchronous cells are operating on the frequency, the first DMTC for the frequency to be used by the wireless device for one or more inter-frequency asynchronous cells operating on the frequency; and

if the indication is set to a value that indicates that there are no asynchronous cells operating on the frequency, the second DMTC for the frequency to be used by the wireless device for one or more inter-frequency synchronous cells operating on the frequency.

6. The method of claim 1 wherein transmitting the system information or the measurement object comprises transmitting the measurement object to the wireless device, the measurement object comprising:

the indication of whether one or more asynchronous cells are operating on the frequency;

if the indication is set to a value that indicates that one or more asynchronous cells are operating on the frequency, the first DMTC for the frequency to be used by the wireless device for one or more asynchronous cells operating on the frequency; and

if the indication is set to a value that indicates that there are no asynchronous cells operating on the frequency, the second DMTC for the frequency to be used by the wireless device for one or more synchronous cells operating on the frequency.

7. The method of claim 1 wherein sending the one or more DMTCs comprises sending both the first DMTC and the second DMTC.

8. The method of claim 7 wherein the system information or the measurement object further comprises a second indication of whether any synchronous cells are operating on the frequency.

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9. A radio access node for a cellular communications network, comprising:
a processor; and

memory comprising instructions executable by the processor whereby the radio access node is operable to:

send, to a wireless device, one or more Discovery Signal Measurement Timing Configurations, DMTCs, for a frequency on which one or more asynchronous cells can be operating, an asynchronous cell being a cell that is unsynchronized with a primary cell of the wireless device;

wherein, in order to send the one or more DMTCs, the radio access node is operable to transmit system information or a measurement object comprising:

an indication of whether one or more asynchronous cells are operating on the frequency;

if the indication is set to a value that indicates that one or more asynchronous cells are operating on the frequency, a first DMTC for the frequency to be used by the wireless device for one or more asynchronous cells operating on the frequency; and

if the indication is set to a value that indicates that there are no asynchronous cells operating on the frequency, a second DMTC for the frequency to be used by the wireless device for one or more synchronous cells operating on the frequency.

10. A method of operation of a wireless device in a cellular communications network, comprising:

receiving one or more Discovery Signal Measurement Timing Configurations, DMTCs, for a frequency on which one or more asynchronous cells can be operating, the one or more asynchronous cells being one or more cells that are unsynchronized with a primary cell of the wireless device, wherein receiving the one or more DMTCs comprises receiving system information or a measurement object comprising:

an indication of whether one or more asynchronous cells are operating on the frequency;

if the indication is set to a value that indicates that one or more asynchronous cells are operating on the frequency, a first DMTC for the frequency to be used by the wireless device for one or more asynchronous cells operating on the frequency; and

if the indication is set to a value that indicates that there are no asynchronous cells operating on the frequency, a second DMTC for the frequency to be used by the wireless device for one or more synchronous cells operating on the frequency; and

utilizing the one or more DMTCs.

11. The method of claim 10 wherein receiving the system information or the measurement object comprises receiving the system information comprising:

the indication of whether one or more asynchronous cells are operating on the frequency, wherein the one or more asynchronous cells are one or more intra-frequency asynchronous cells;

if the indication is set to a value that indicates that one or more asynchronous cells are operating on the frequency, the first DMTC for the frequency to be used by the wireless device for one or more intra-frequency asynchronous cells operating on the frequency; and

if the indication is set to a value that indicates that there are no asynchronous cells operating on the frequency, the second DMTC for the frequency to be used by the wireless device for one or more intra-frequency synchronous cells operating on the frequency.

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12. The method of claim 11 wherein the system information is a System Information Block type 3 (SIB3) information element.

13. The method of claim 10 wherein receiving the system information or the measurement object comprises receiving the system information comprising:

the indication of whether one or more asynchronous cells are operating on the frequency, wherein the one or more asynchronous cells are one or more inter-frequency asynchronous cells;

if the indication is set to a value that indicates that one or more asynchronous cells are operating on the frequency, the first DMTC for the frequency to be used by the wireless device for one or more inter-frequency asynchronous cells operating on the frequency; and

if the indication is set to a value that indicates that there are no asynchronous cells operating on the frequency, the second DMTC for the frequency to be used by the wireless device for one or more inter-frequency synchronous cells operating on the frequency.

14. The method of claim 13 wherein the system information is a System Information Block type 5 (SIB5) information element.

15. The method of claim 10 wherein receiving the system information or the measurement object comprises receiving the measurement object, the measurement object comprising:

the indication of whether one or more asynchronous cells are operating on the frequency;

if the indication is set to a value that indicates that one or more asynchronous cells are operating on the frequency, the first DMTC for the frequency to be used by the wireless device for one or more asynchronous cells operating on the frequency; and

if the indication is set to a value that indicates that there are no asynchronous cells operating on the frequency, the second DMTC for the frequency to be used by the wireless device for one or more synchronous cells operating on the frequency.

16. The method of claim 10 wherein receiving the one or more DMTCs comprises receiving both the first DMTC and the second DMTC.

17. The method of claim 10 wherein the system information or the measurement object further comprises a second indication of whether any synchronous cells are operating on the frequency.

18. A wireless device for a cellular communications network, comprising:

a transceiver;

a processor; and

memory comprising instructions executable by the processor whereby the wireless device is operable to:

receive one or more Discovery Signal Measurement Timing Configurations, DMTCs, for a frequency on which one or more asynchronous cells can be operating, the one or more asynchronous cells being one or more cells that are unsynchronized with a primary cell of the wireless device wherein, in order to receive the one or more DMTCs, the wireless device is operable to receive system information or a measurement object comprising:

an indication of whether one or more asynchronous cells are operating on the frequency;

if the indication is set to a value that indicates that one or more asynchronous cells are operating on the frequency, a first DMTC for the frequency to

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be used by the wireless device for one or more
asynchronous cells operating on the frequency;
and
if the indication is set to a value that indicates that
there are no asynchronous cells operating on the 5
frequency, a second DMTC for the frequency to be
used by the wireless device for one or more
synchronous cells operating on the frequency; and
utilize the one or more DMTCs.

* * * * *

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